Financial Development and Innovation-led Growth: Is Too Much Finance Better?

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Abstract

We show that the expansion of financial sector may hurt innovative activities and hence the innovation-led growth, using data on 50 countries over the 1990-2016 period. Countries with higher level of financial development are found to have a smaller positive or insignificant effect on innovation. The marginal effect of innovation on growth is a decreasing function of financial development. Using a dynamic panel threshold method we re-examine the possible non-linearity between finance, innovation and growth. We find that innovation exhibits an insignificant effect on output growth when credit to the private sector exceeds a threshold level of about 60% as a share of GDP. These results are not driven by banking crises, the long run effect of 2007-2008 financial crisis, or the ongoing European sovereign debt crisis.

Keywords: Financial development; Innovation; Growth; Threshold effect
JEL Classification: G15; O31; O40

1 Introduction

The basic Schumpeterian model of economic growth considers technological progress as an important factor for long-run growth (Schumpeter (1934)). The positive role of innovation on growth has been discussed and tested by a number of subsequent works (Scherer et al. (1986), Freeman et al. (1994)). Among determinants of innovation, R&D expenditure, talents, technology transfer and networking have been identified as important factors that shape and promote innovation and hence the innovation-led growth (Love and Roper (1999), Acemoglu et al. (2016)). Recent years

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have seen an expansion in financial sector around the world with several implications on innovation and growth. First, financial development may facilitate innovation activities by alleviating credit constraints on the flow of capital to its most productive projects and hence promote R&D financing and growth (e.g. King and Levine (1993a,b), Benfratello et al. (2008), Brown et al. (2009), Amore et al. (2013), Gorodnichenko and Schnitzer (2013), Hsu et al. (2014) and Levine et al. (2017)). Second, the expansion of financial sector has raised the concern of "brain drain" between industries (Boustanifar et al. (2017)). Third, credit expansion shows its dark side on resource allocation, both on physical and human capital (Tobin (1984), Cecchetti et al. (2015) and Borio et al. (2016)). Collectively, these competing theories and evidences lead to the following questions: What is the overall effect of financial development on innovation? Will the monotonic relationship between finance and innovation hold as financial sector continues to expand? How does financial development affect innovation-led growth?

This paper attempts to answer these questions empirically. Previous studies on the finance-innovation-growth nexus support the existence of a positive monotonic relationship. However, we explore whether there exists a non-monotonic relationship with a possible threshold effect. Specifically, our study is conducted in two parts. First, we examine the nonlinear relationship between financial development and innovation. Second, we study the role of financial development on the innovation-growth relationship. To this end, we use two different methods to explore the possible nonlinearities. Initially we qualitatively split the sample into different subgroups by the level of financial development and income and apply a system-GMM to estimate the effect of financial development on innovation for each group. The system-GMM methodology allows us to use the lagged value of dependent and independent variables to account for potential endogeneity issues. However, this method may not give precise estimation on the threshold value at which the effect changes, if any. For this reason, we also employ a novel GMM model developed by Seo and Shin (2016). This model extends the Hansen (1999) and Caner and Hansen (2004) static panel threshold model and the Kremer et al. (2013) dynamic panel threshold model by allowing for the transitional variable and other covariates to be endogenous. The Seo and Shin (2016)'s method requires the use of balanced panel with large n and small T. We curtail the data to fit the model using five years non-overlapping average data, which is also consistent with the related growth literature (see for example Asimakopoulos and Karavias (2016) and references therein). To guarantee that our data contains roughly equal proportion of developing and developed countries, we consider only the financial development in credit market. Thus, we end up with a balanced panel of 50 countries from 1990 to 2016, including 22 developing and 28 developed countries.

Our results can be summarized as follows. First, we find that the overall effect of financial development on innovation is positive. However, this effect is lower when financial development exceeds a certain level. Second, the overall effect of innovation on growth is positive and heterogeneous across the various levels of financial development. Third, the dynamic panel threshold method shows the existence of non-linear relationship between innovation and growth with a threshold value around 60% of GDP. Our threshold value reflects the difference between the threshold model used in our paper, dealing with monotonicity and endogeneity simultaneously compared to previous studies, as well as the impact of global financial integration. Financial integration may enhance the positive effect of financial development on innovation and growth leading to a smaller threshold value of financial development.

Credit expansion may lead to banking crisis or economic crisis and the innovation activities may be dampened during the crisis (Döner (2017), OECD (2012), Comin and Gertler (2006) and Francois and Lloyd-Ellis (2008)). Therefore, the observed vanishing effect may be caused by banking crisis. To check whether the threshold effects are affected by crisis, we interact the crisis dummy with the variable of interest and estimate the difference in the effect between crisis and tranquil period. Our findings indicate an insignificant negative effect on the interaction term.

The 2007-2008 financial crisis may have a long run negative effect on innovation. In our sample, 39.2% of the high income countries' innovation never recover to their pre-crisis level and 22.7% of middle income countries' innovation sink after the financial crisis. The subsequent European sovereign debt crisis continually depresses the innovative activities for many countries in Euro Zone (EZ) and probably countries outside the EZ since 2010. We find that 67.86% of high income countries experienced a reduction in innovation after 2010 and 50% of middle income countries have seen a sluggish recovery in innovation. The situation does not get ameliorated even for countries with high quality of governance. During the same period, however, we find that the level of credit is higher in high income countries and in countries with high governance quality. The documented non-linearity using full sample may be contaminated by the ongoing European sovereign debt crisis and the long run negative effect of the recent financial crisis. Using a sub-sample from 1990 to 2009, we find a robust non-linearity between finance, innovation, and growth.

Our paper relates and contributes to several strands of theory relating growth, innovation and financial-market development. Our findings provide consistent results with several theoretical predictions and recent empirical studies. Regarding the finance-innovation nexus, Tobin (1984) mentioned that too many financial activities may misallocate resources, both physical and human capital, from production sector to less productive financial sector. Cecchetti et al. (2015) and Borio et al. (2016) elaborate this idea by showing that less productive but more pledgeable projects are easily financed during financial sector expansions. When credit inflates, workers, especially the talented STEM workers, are lured into low productivity gains sectors due to high finance compensation (Axelson and Bond (2015), Boustanifar et al. (2017) and Célérier and Vallée (2018)). Both channels hurt real sector by reducing the innovation capacity. Weinstein and Yafeh (1998), using firm level data, show that close firm-bank ties may facilitate firms to access credit, but it may also prevent firms from involving risky and high return projects such as R&D activities. Morales (2003) introduces financial sector in an endogenous growth model and shows that financial activity may have two opposite external effects on research productivity. On one hand, the positive effect of financial activity will spill over to other sectors of the economy and promote productivity. On the other hand, this positive externality would induce creative destruction process and discourage the incentives to invest in R&D. Inspired by the work of Klette and Kortum (2004) and Akcigit and Kerr (2018), where different types of innovations are introduced in a growth model, Philippe et al. (2018) argue that the introduction of financial development into these models may result in two competing effects. First, potentially good innovators may face less financing constraints to enter the market due to the development of financial market, which in turn is beneficial to aggregate innovation and growth. Second, less credit constraints may make it easier for less efficient firms to remain in the market and prevent more efficient innovators from entering the market. This in turn may be harmful to aggregate innovation and growth. As financial sector continues to expand in modern economy and credit constraints are alleviated for many firms, it is uncertain whether the overall effect of financial development on innovation is monotonic or not.

In terms of the finance-growth relationship, our results are consistent with several recent empirical papers showing that "too much finance" may hurt economic growth. Using country- and industry-level panel data, Arcand et al. (2015) test the non-linearity between private credit and growth by including both the private credit and its square term into the growth equation, deriving a threshold point of around 100% of GDP. Private credit tends to promote growth in the lower regime, while the effect turns negative in the upper regime. In a similar fashion, Cecchetti and Kharroubi (2012) estimate the threshold to be nearly 100% of GDP. The baseline models used in these two studies, however, may suffer from endogeneity and multicollinearity issues (see Law and Singh (2014) for discussions). In an attempt to control for these issues, Law and Singh (2014) use a panel threshold model proposed by Kremer et al. (2013) to re-estimate the possible threshold effect of private credit on growth and they obtain a threshold of around 88% of GDP. Using both a dynamic panel threshold approach and an autoregressive distributed lag ARDL(p,q) model, Samargandi et al. (2015) establish the non-monotonic effect of financial development and growth among middle income countries, suggesting a turning point around 91% of GDP. However, most of these studies do not explicitly or directly explore the sources of non-linearity between financial development and growth.

The above discussions may generate two implications. First, financial development may have a diminishing effect on the rate of innovation, such effect transmits to productivity and slows down aggregate growth. Second, financial development may also make innovations per se less effective in promoting growth. For an innovation to be effective in promoting productivity and aggregate growth, necessary complementary inventions and follow-up investment in productive capital is required. However, as credit market expands, banks may also prevent firms from involving risky projects such as R&D activities, causing less productive but more pledgeable projects to be easily financed. The relatively less investment of productive capital may prolong the implementation and restructuring lags and reduce the contribution of innovation on productivity and economic growth.

Most related to our work are studies by Law et al. (2018) and Xiao and Zhao (2012). Law et al.

(2018) document an inverted U-shaped relationship between financial development and innovation using a panel of 75 countries over 1996-2010. Their analysis is embodied in the context of institution quality where the effect of finance on innovation depends upon the quality of institutions. Our study does not consider the context of institution quality because there is high overlapping between countries with high quality of governance, high income countries and countries with high level of financial development. Xiao and Zhao (2012) find that credit market development significantly enhances firm innovation in countries with lower government ownership of banks, while the effect turns to insignificant or even negative when government ownership increases.

Our study contributes to the related literature in three ways. First, we provide direct evidences that finance-innovation-growth nexus follows a non-linear relationship as credit expands. The findings show that the threshold effect between finance and innovation serves as a possible channel through which too much finance may harm growth. Second, we also find that the effect of innovation on growth is weakened by too much finance. Finally, this empirical work is conducted using a novel GMM method developed by Seo and Shin (2016). This model extends the Hansen (1999) and Caner and Hansen (2004) static panel threshold model and the Kremer et al. (2013) panel threshold model by allowing for the transitional variable and other covariates to be endogenous. Therefore, this new dynamic panel threshold model accounts for the endogeneity issue that is ignored by previous studies.

The rest of this paper is organized as follows. Section 2 specifies the empirical models and describes the data. Section 3 presents and discusses the results. Section 4 concludes.

2 Empirical Specifications and Data

2.1 Empirical strategies

The empirical analysis consists of two parts. First, we examine the non-linear relationship between financial development and innovation. Second, we estimate how financial development affect the innovation-growth relationship. To this end, we employ two different methods: linear system GMM and a dynamic panel threshold.

2.1.1 Linear system-GMM

In the linear system-GMM method, we qualitatively split the sample into two groups by the level of financial development. We initially sort the countries by their level of financial development. Then we define the top 25 countries as high financial development countries and the bottom 25 countries as the low financial development countries. This strategy may not give a precise estimation of the threshold level of financial development, but it enables us to build an intuition about the possible nonlinearity between finance, innovation and growth. In our sample, high income countries are typically associated with high level of financial development. As a robustness check, we also split the sample into two groups by their level of GDP per capita: high income countries and middle incomes[1]. For each of the five groups, we consider the following specification for the innovation equation:

$$innovation_{it} = \rho innovation_{it-1} + \alpha_j FD_{it} + \beta \mathbf{X}_{it} + u_i + v_t + e_{it} \quad (1)$$

where $innovation_{it}$ and $innovation_{it-1}$ are the current and lagged indicator of innovation. $\mathbf{X}_{it}$ denotes the control set including FDI, schooling, population, GDP per capita, and the protection for intellectual property right. FD_{it} denotes the financial development indicators. u_i is the country fixed effect that absorbs the effect of country level variation, v_t captures the time fixed effect, which controls for possible cross-sectional dependences. e_{it} captures the stochastic error term. j is an indicator of high and low level of financial development or high and middle income countries. System-GMM use the lagged dependent variable and regressors to instrument for possible endogeneity issues. In our setting, there are two possible causes of endogeneity: the omitted variable issue and reverse causality between financial development and innovation. First, if $innovation_{it-1}$ is correlated with e_{it}, then in the first-difference transformed equation, $\Delta innovation_{it-1}$ would correlate with Δe_{it}. Second, technology change relating to communication and data processing have greatly promoted the development of financial services (Frame et al. (2014)). As instruments we lag our variables twice for the difference equation and once for the level equation. All the variables used are five years non-overlapping average data.

Next, we consider how financial development affect the innovation-led growth. In a similar spirit, we split the sample by the level of financial development and GDP per capita. Specifically, we consider the effect of innovation on growth for the high level financial development countries, low level financial development countries, high income countries and middle income countries. For each group we consider the following growth regression:

$$y_{it} = \rho y_{it-1} + \alpha innovation_{it} + \gamma \mathbf{Z}_{it} + u_i + \tau_t + e_{it} \quad (2)$$

where y_{it} and y_{it-1} represent current and lagged growth rate of GDP per capita, respectively. $innovation_{it}$ is the same as in the innovation regression. $\mathbf{Z}_{it}$ is the control set including government expenditure (%GDP), trade (%GDP), investment (%GDP), inflation rate (%), Schooling and initial GDP per capita. u_i, τ_t and e_{it} refer to country fixed effects, time fixed effects, and stochastic error term, respectively. Notice that our specification is different from conventional regression specified in growth literatures, where y_{it} usually refers to GDP per capita. In our sample, GDP per capita is quite persistent and the Harris-Tzavalis test (Harris and Tzavalis (1999)) shows that

[1]In our sample, there are no low income countries due to the unavailability of data in indicators of financial development, innovation indicators, and other variables

GDP per capita is not stationary[2]. Using growth rate of per capita GDP instead of the level does not change our interpretation of the coefficient on variables of interest (see also Asimakopoulos and Karavias (2016)).

As a robustness check, we also consider the interaction between financial development and innovation. The specification is as follow:

$$y_{it} = \rho y_{it-1} + \alpha innovation_{it} + \beta FD_{it} * innovation_{it} + \gamma \mathbf{Z}_{it} + u_i + \tau_t + e_{it} \tag{3}$$

The marginal effect of innovation on growth is $\hat{\alpha}+\hat{\beta}*FD_{it}$. According to the theoretical prediction, higher level of financial development reduces productivity via brain drain or misallocation in physical capital and the effect of innovation on growth is lower in countries with higher level of financial development. Therefore, if there exists any "diminishing effect" for the innovation-growth nexus due to financial development, α is expected to be greater than zero, while β is expected to be negative.

2.1.2 Dynamic panel threshold model with endogenous threshold variable

Although the linear system-GMM method helps us to build an intuition about the non-linearity, it gives neither a rigorous test on the linearity nor the estimated threshold value at which the effect begins to change. For this reason, we examine the above two questions using a novel GMM method developed by Seo and Shin (2016). This model extends the Hansen (1999) and Caner and Hansen (2004) static panel threshold model and the Kremer et al. (2013) panel threshold model by allowing for the transitional variable and other covariates to be endogenous. To estimate the coefficients, they propose a First Difference GMM (FD-GMM) transformation. This algorithm relaxes the exogeneity assumption on regressors and threshold variable and guarantee that the estimators follow a normal distribution asymptotically, which validates the use of Wald test for standard statistical inference on threshold and other parameters. For the innovation equation, we extend equation (1) to:

$$innovation_{it} = \rho innovation_{it-1} + \alpha_L FD_{it} I(FD_{it} \leq \gamma) + \alpha_H FD_{it} I(FD_{it} > \gamma) + \beta \mathbf{X}_{it} + u_i + \tau_t + e_{it} \tag{4}$$

Note that, the financial development is treated as regime dependent variable as well as transitional variable. $I(\cdot)$ is an indicator of the regime. γ is a hypothetical threshold value. The subscripts L and H on α refer to lower and upper regime, respectively. The instrument variables include the exogenous variables, the lagged dependent variable and other covariates.

In a similar spirit we estimate our growth equation using a dynamic panel threshold model. In

[2] We use H-T test because our sample contains relatively larger panel and smaller time period, Harris-Tzavalis test best fit sample structure like this.

particular, we treat financial development as the threshold variable, while innovation is the regime dependent variable changing according to the estimated threshold of financial development. The notation used here is similar to the innovation equation (1). Therefore, the growth model presented in equation (2) becomes:

$$y_{it} = \rho y_{it-1} + \beta_L innovation_{it} * I(FD_{it} \leq \gamma) + \beta_H innovation_{it} * I(FD_{it} > \gamma) + \theta \mathbf{Z}_{it} + u_i + \tau_t + e_{it} \tag{5}$$

For equations (4) and (5), we use the non-linearity test $supW = supW_n(\gamma)$ statistics upon the null of $\alpha_L - \alpha_H = 0$ and $\beta_L - \beta_H = 0$, where $W_n(\gamma)$ is the standard Wald statistic for each fixed γ.

2.2 Data and summary statistics

A complete picture of financial development includes the development in both credit and equity markets. Due to the limitation of stock market data in developing countries plus the fact that firms financing in developing countries is mainly through internal retained profits and external credit market, we constraint our study to credit markets. The private credit by banks and other financial institutions as a share of GDP is preferred in finance-growth literature (Levine et al. (2000)). As robustness checks, we also consider credit issued to private sector by money deposite banks (%GDP), demostic credit to private sector (%GDP) and liquidity liability (%GDP). All the indicators are obtained from World Bank Financial Structure Database.[3] The banking crisis data is obtained from Laeven and Valencia (2013) Systemic Banking Crises Database (1970-2011). Inspired by Baker et al. (2016), the data of banking crisis are extended to 2016 by searching for keywords that indicate a banking crisis for each country between 2012 and 2016. The keywords used include bank run, bank crisis and illiquidity.[4]

The innovation is measured by patent applications per 100 billion USD obtained from World Intellectual Property.[5] This indicator is measured as total equivalent counts by applicant's origin. We use patent application as an indicator of innovation to account for the truncation issue, since there are typically two to three years grant lags between application and grant year. For example, the mean years of grant lags for USPTO fluctuates between 26 months and 32 months and the distribution of grant lags varies across fields of inventions (Squicciarini et al. (2013)). Another reason is that the application year better captures the actual effective time of innovation (Griliches

[3] In our sample, New Zealand missed the indicators of financial development between 2012 and 2016 . To fill the gaps, we use data for Broad Money, Private sector credit, Domestic credit, Exchange rate between New Zealand Dollar and US Dollar, and Gross Domestic Product from Reserve Bank of New Zealand(`https://www.rbnz.govt.nz/statistics`) to construct the missing indicators in World Bank Financial Structure Database. In New Zealand, the private credit by deposit banks and Private credit by banks and other financial institution are identical.

[4] Using this method, we detected several banking crisis for the following countries: China in 2014; Greece in 2015; Portugal in 2014; Spain between 2012 and 2014

[5] We also consider using patent applications per million population as indicator of innovation, the correlation between these two indicators is 0.9554 and the results are quite similar.

et al. (1986)) and an invention starts to affect the real economy since its inception (Hsu et al. (2014)). We have the following considerations when constructing this variable. First, the selection of countries and period of time is based on the availability of annual observations on patent applications. Second, countries with many zeros or very small amount of patents and missing values are not considered. Third, countries in our sample are expected to exhibit different stages of development.

We also use the number of utility models as another measure of innovation. This indicator is obtained from WIPO. The major differences between patents and utility models are as follows. First, the requirements for acquiring a utility model are less stringent than for patents. Second, utility models are cheaper to obtain and to maintain. Third, the term of protection for utility models is shorter than for patents. Therefore, in many countries, utility models are sometimes referred to as "second-class patents". Thus, patents and utility models represent different quality of innovation.[6] Throughout this paper, patents are used as the primary indicator of innovation in the regressions. However, we provide the estimation results for utility models in the dynamic threshold regression as an additional robustness check. The last indicator of innovation we use as a robustness check is R&D expenditure (%GDP)[7], which is collected from OECD and UNESCO. We drop four countries due to missing values, reducing our sample reduces to 46 countries. However, our threshold estimations remain robust even with the reduced sample size.

For controls in innovation regression, we include net inflow of foreign direct investment (%GDP) measuring the technology diffusion effect; population, which accounts for possible scale effects in the process of innovation; mean years of schooling; GDP per capita; and protection for intellectual property right. Regarding the growth regression, the dependent variable is the growth rate of GDP per capita and the variables of interest are innovation and financial development. We consider innovation as regime dependent variable and take financial development as the threshold variable. The controls include general government final consumption (%GDP), capital formation (%GDP), CPI-based inflation rate (%), trade openness (%GDP), mean years of schooling, and initial GDP per capita. To remove the influence of cyclical components of data, we use five years non-overlapping averages. The final panel consists of 50 countries from 1990 to 2016, among which, 28 are high income countries and the rest are upper and lower middle income countries. Table A7 provides the definition, construction and source of each variable. Summary statistics are shown in Table indicating a significant heterogeneity in innovation and financial development across countries.

[Place Table 1 about here]

[6] This strategy can also be seen at Cai et al. (2018)

[7] Some studies think that R&D indicator does not capture innovation very well because it belongs to input and provides insufficient information on the output of R&D activities. Despite this, we think R&D indicator is still useful as an alternative indicator to check the robustness of our results because it retains some predictive power about the innovative output.

3 Results

As a starting point, we build an intuition about the relationship between financial development and innovation by qualitatively splitting the sample into two groups: high financial development countries and low financial development countries. Specifically, the countries are ranked by the level of financial development in an ascending order. Then we define the top half of the sample as countries with high level of financial development, while the other half is defined as countries with low level of financial development. Figure 1 shows that as financial development continues to expand, its effect on innovation tends to decrease. This illustration seems to match the prediction of existing theories, but possible non-linearities might exist via other sources. Next, we present the empirical results.

[**Place Figure 1 about here**]

3.1 Results for linear system-GMM

3.1.1 Financial development and innovation

Table 2 reports the basic results for equation (1). In this table, we use private credit as a proxy for financial development and the percentage change in patent application as dependent variable. We implement a two step system-GMM estimation for equation (1). Due to the downward bias in the computed standard errors of two-step estimation, the Windmeijer correction is applied. In each regression, we take population as an exogenous variable, while considering the rest as endogenous variables. The full sample results show that the overall effect of private credit on innovation is positive and significant. Population, FDI and GDP/capita exhibit a non-negative but insignificant effect on innovation. In addition, schooling and protection for intellectual property right have a negative but insignificant effect.

Next, we consider the effect of private credit change as the level of financial development increases. We find that the effect of private credit on innovation for middle income countries is higher than that of high income countries and that the overall effect lies between 0.183 and 0.394. Moving to the low and high financial development countries, we find a similar pattern that the effect in low financial development countries is greater than that of high financial development countries. Again, the overall effect lies between the two estimated effects. The p-value of the AR(2) test and Hansen J-test are reported at the bottom of Table 2. The AR(2) test show no significant correlation between the error term and the lagged dependent variable, which indicates that the use of two lags for the dependent variable serve as valid instruments. The Hansen test shows that the specifications do not suffer from over-identification issues. This exercise is consistent with the intuition in Figure 1 and confirms our hypothesis that “too much finance” would hurt innovative activities. In Table A1 of appendix, we provide robustness checks for regression (1) using other indicators of financial development and we find a similar pattern as in Table 2.

[Place Table 2 about here]

3.1.2 Financial development, innovation, and growth

This part studies how financial development affects the innovation-growth relationship. Results in Tables 2 and A1 show that innovation may be regime dependent upon the level of financial development, since innovation is a determinant factor for long-run growth, it is possible that the effect of innovation on growth is conditional on the level of financial development. Our hypothesis is that higher level of financial development hurts innovation and related investment in complementary inventions and structure, reducing its effect on growth. We estimate equation (3) under: i) full sample; ii) middle and high income groups; and iii) high and low level of financial development groups. Table 3 provides the results using private credit by banks and other financial institutions (%GDP) as a proxy for financial development (similar to Table 2), and patent per 100 billion USD as an indicator of innovation. Table 3 shows that the overall effect of patent on growth is positive and significant. When we split the sample into middle and high income countries, the effect of innovation for middle income countries is larger than that of high income countries. The same pattern appears when we split the sample into low and high level of financial development countries. The effect is positive and significant for low financial development countries, while it is positive and non-significant for high financial development countries. Also notice that the overall effect lies between the effects of the two subgroups.

In terms of the coefficients of other covariates, government consumption affects negatively economic growth, which is consistent with the related literature. High income and high financial development countries benefit from international trade, while middle income and low financial development countries do not. Developing countries are featured with unsound laws and regulations, less efficient financial market and low level of human capital. These may impede its capacity to attract foreign investment and to absorb the frontier technologies. Moreover, the negative coefficient of initial GDP per capital captures the convergence effect. Table 3 also reports AR(2) and Hansen J-test indicating valid specifications. We further check the robustness of our estimations using alternative indicators of financial development and we find that the results reported in Table 3 remain valid (see Table A2 in the appendix).

[Place Table 3 about here]

3.1.3 Interaction analysis

The results in the previous sub-sections deliver a signal that the effect of innovation on growth may be heterogeneous across countries. Based on this observation, we extend equation (2) to:

$$y_{it} = \rho y_{it-1} + \alpha_i innovation_{it} + \gamma \mathbf{Z}_{it} + u_i + \tau_t + e_{it} \tag{6}$$

where the parameter α_i is country specific parameter and depends on financial development

$$\alpha_i = \alpha + \beta FD_{it} \tag{7}$$

As discussed in introduction, countries with higher level of financial development may hurt innovation and its effect on growth. We therefore expect a negative sign on β. Combining equations (6) and (7) we can get the form of equation (3).

Table 4 reports the results of the interaction analysis. For every indicator of financial development we find consistent results that the coefficient on interaction term is negative and that the effect of patent is positive and significant. The average marginal effect of patent on growth is $\alpha + \beta * FD_{it}$, since $\alpha > 0$ and $\beta < 0$ the overall effect of patent is a decreasing function of financial development. In Figure A2 in the appendix we simulate the average marginal effect of patent on growth for all the indicators of financial development. Our findings suggest that the marginal effect is a downward trend line and mainly positive. This is consistent with the results reported in Table 3.

[**Place Table 4 about here**]

3.1.4 Credit expansion, Banking crisis, Innovation, and Growth

A number of recent empirical studies have documented a "too much finance" pattern using both aggregate and industrial level data. Major explanations to this evidence include credit expansion, induced financial instability and economic volatility (Rajan (2006), De la Torre et al. (2011)), as well as misallocation of resources (Tobin (1984), Cecchetti et al. (2015)). We find that, in our sample, banking crisis follows closely the credit expansions. Figure A1 in the appendix shows the evolution of private credit for U.S., UK, Japan, Malaysia, and China. For each country, a banking crisis takes place when credit tends to expand. For example, Malaysia experienced a banking crisis between 1997-1998. During this period the private credit level is at the highest level in our sample. Table 5 shows the difference in financial development between crisis and tranquil period. On average, the level of private credit is significantly higher than in tranquil period. Banking crisis may affect innovation performance and investments via several mechanisms (Döner (2017), OECD (2012)). For example, a crisis causes a reduction in the demand for products dampening the incentives to innovate. In addition, firms may suffer from credit constraints and difficulties in accessing financing during banking crisis causing a reduction in riskier activities such as R&D expenditurers. This pro-cyclical pattern of R&D and innovation has been observed over various business cycles and for a variety of countries (e.g. Comin and Gertler (2006), Francois and Lloyd-Ellis (2008)).

The "diminishing effect" documented in Tables 3 and 4 may be attributable to the potential negative effect of banking crisis on innovation. Therefore, we consider the interaction between innovation and banking crisis in the following equation:

$$y_{it} = \rho y_{it-1} + \alpha innovation_{it} + \beta BC_{it} + \delta innovation_{it} \times BC_{it} + \gamma \mathbf{Z}_{it} + u_i + \tau_t + e_{it} \tag{8}$$

where BC_{it} is the dummy for banking crisis for country i at year t. The value of this dummy is 1 if there is a banking crisis at year t and 0 for tranquil periods. δ measures the difference effect of finance on innovation between crisis and tranquil period. Arcand et al. (2015) show that economic volatility does not play a major role in the vanishing effect of financial development. Thus, we expect that banking crisis does not impose a significant impact on innovation-growth nexus. The results in Table 6 show that banking crisis and patent have the expected signs. Regarding the interaction term, we do not find a significant negative effect which means that the vanishing effect of innovation on growth is not a result of banking crisis.

[Place Tables 5 and 6 about here]

3.1.5 The European sovereign debt crisis and long run impact of financial crisis since 2009

The 2007-2008 financial crisis may have a long term negative impact on innovative activities and innovation-led growth. The potential long-term negative effects on innovation and growth, if any, can transmit through the negative effects on human capital, future investment on R&D activities, technological leadership and public support systems for innovation (OECD (2012)).

In order to assess the heterogeneous impact of post financial crisis on innovation for different types of countries, we divide our sample into four groups: high income countries, middle income countries, countries with high quality of governance and countries with low quality of governance. We consider the quality of governance because the potential negative effect on innovation may depend on the soundness of the quality of governance.[8] We use the index of quality of governance (QOG), proposed by Teorell et al. (2018), to measure the quality of government. A country is

[8]The literature on the effect of Basel Core Principles for Effective Bank Supervision (BCP) show that better supervisory governance and supervisory unification were generating a positive impact on financial sector stability and banking soundness pre-2008 financial crisis. However, these conclusions do not hold when the period examined covers the 2007-2008 financial crisis. Quintyn et al. (2011) find a negative relationship between supervisory governance and economic resilience using a panel of 100 countries. Countries with a solid supervisory governance system hurt more during the 2007-2008 crisis. If this evidence is reliable, then one possible explanation is that innovation recovers slowly or is unable to return to pre-crisis level for countries with high quality of governance.

considered as high QOG if the index is above the 50^{th} percentile of all countries.

Panel A of Table 7 provides a brief summary of the innovation resilience after the 2007-2008 financial crisis. To assess how financial crisis affects the innovation in the long run, we construct three indicators to measure the innovation recovery after the financial crisis. The first indicator is called Sinking Ratio, which is defined as the ratio of countries whose innovation level does not recover to its pre-crisis level through the whole post financial crisis period examined in our sample. We use the average level of innovation in year 2005 and 2006 as the pre-crisis level of innovation. Meanwhile, year 2009 is set as the initial year after the financial crisis. The sinking ratio shows that 39.2% of high income countries never recover to its pre-crisis level of innovation between 2009-2016. Similarly, 38.4% of high QOG countries do not fully recover to its pre-crisis level of innovation. However, the sinking ratio is lower for middle income and low QOG countries. Next, we consider how long does it take for a country to recover from crisis. The average years of recovery is defined as the average years needed to return to pre-crisis level for those recovered countries. We find that middle income and low QOG countries take longer to recover to pre-crisis level than that of high income and high QOG countries. The average years needed to recover for high income and high QOG countries is between 0.43 and 0.5, however, this time is around 1.4 for middle income and low QOG countries. We also take a look at the years needed for the first positive growth of innovation after crisis, which is defined as the average years of first turning point. We find that for each of the four groups, countries tend to recover in a quarter after 2009. Overall, middle income and low QOG countries take longer to recover to pre-crisis innovation level, but the sinking ratio is lower than that of high income and high QOG countries. This indicates that the self-healing ability after crisis in middle income and low QOG countries is stronger. These facts are consistent with the pattern in Quintyn et al. (2011).

The financial crisis may have a significant role on the ongoing European sovereign debt crisis (ESDC) started in late 2009 and early 2010 through international financial linkages, but ESDC should not be simply taken as the consequence of the recent financial crisis. Many factors contribute to the ESDC.[9] In our sample, there are 17 European countries, which are among the high income countries. Although 12 out of 17 countries tend to recover to its pre-crisis level of innovation very quickly, most of these European countries are affected during the ESDC. To measure how ESDC may affect countries' innovation after 2010,[10] we construct a simple indicator measuring the ratio of countries with negative average growth rate of innovation since 2010. As shown in row 4 of panel A in Table 7, 67.86% of high income countries experience negative growth of

[9]For example, the globalization of finance; easy credit conditions during 2002-2008 period that encouraged high-risk lending and borrowing practices; international trade imbalance; the inaccordance between unified Euro Zone monetary policy and independent fiscal policy of individual sovereign country; and possibly the inability of the macroeconomic model employed by European Central Bank

[10]Notice that, we cannot attribute a country's declination of innovation after 2010 simply to the impact of ESDC, for example, we find that Argentina and Brazil show a negative trend. This, however, could be a compound effect of both long-run effect of financial crisis and other domestic factors.

innovation, while this figure is 50% for middle income countries. For high QOG countries, 69.23% of them show negative growth rate of innovation. This indicator is 50% for low QOG countries. Regarding the European countries in our sample, 14 out of 17 show a negative trend in innovation during this course. Over the same period, the level of financial development, as shown in panel B of Table 7, is higher for high income and high QOG countries.

Table 8 provides a test on the impact of post financial crisis and ongoing European sovereign debt crisis on innovation. We define the dummy $LC = 1$ for the years after 2009 and $LC = 0$ if otherwise. The interaction term between financial development and LC is negative. This indicates that the ongoing European sovereign debt crisis and post financial crisis impose a significant negative effect on innovation.

Combining these facts, it is possible that the diminishing effect of finance on innovation-led growth is caused by the ongoing ESDC and long run negative effect of financial crisis. To check the robustness of our results, we delete the sample after 2010 to rule out the influence of post financial crisis and European Debt Crisis. The results in Table 9 use private credit as indicator of financial development[11] and show that the pattern is quite similar to that of the full sample. In the growth regression, the overall effect of patent is positive and higher for middle income and low level of financial development countries. This shows that the non-linearity between finance, innovation and growth is robust and independent of the financial crisis and European sovereign debt crisis.

[**Place Tables 7, 8, and 9 about here**]

3.1.6 Brief summary

The results illustrated in this sub-section reveal the existence of possible non-linearity between financial development, innovation and growth. Countries with higher level of financial development tend to have a lower rate of innovation and growth. The results are robust under a series of robustness checks. However, in the above analysis we slpit our sample using qualitative characteristics and the threshold at which the non-linearity occurs is not rigorously estimated. To quantitatively measure whether there is a threshold for the finance-innovation-growth nexus, we use a dynamic panel threshold methodology developed by Seo and Shin (2016).

3.2 Dynamic Panel Threshold Result

Seo and Shin (2016)'s model extends Hansen (1999) and Caner and Hansen (2004) static panel threshold model and Kremer et al. (2013) dynamic panel threshold model by allowing for the transitional variable and other covariates to be endogenous and for unobserved individual heterogeneity. To estimate the coefficients they propose a First Difference GMM (FD-GMM) transfor-

[11] We also use other indicators of financial development for robustness check, and the results are similar.

mation. This algorithm relaxes the exogeneity assumption of regressors and threshold variable and guarantees that the estimators follow normal distribution asymptotically, which validates the use of Wald test for standard statistical inference on threshold and other parameters. The GMM estimators are obtained through a two-step procedure.[12]

3.2.1 Innovation regression

In innovation regression, equation (4), we consider financial development as a threshold variable as well as a regime dependent variable. Financial development could be endogenous due to omitted variables and due to the reverse causality between technological progress and financial services. Technology changes relating to telecommunications and data processing have greatly spurred financial innovations and services in commercial banking that have facilitated secondary markets for retail loans, such as credit card debt and mortgages. For example, the introduction of Automated Teller Machines (ATMs), Debit Cards, Online Banking and Prepaid Cards have significantly enhanced the banking account access and amount of credits (Frame et al. (2014)). It is hence necessary to take the endogeneity issue of financial development into account. Previous panel threshold methods cannot handle the endogeneity issue of the threshold variable and other covariates. Seo and Shin (2016)'s model construct the set of instrumental variables using the lagged dependent variable, the threshold variable and other covariates.

Table 10 shows the results for every indicator of financial development using dynamic panel threshold method. For private credit in column (1), the effect of FD is positive and significant in the lower regime, while it becomes insignificant in the upper regime. The estimated threshold value of banking credit is 48% and the linearity test indicates an overall significant non-linear relationship. In addition, the over-identification test (J-test) indicates no over-identification issues. Moving from column (2) to (4), we find consistent results with that of private credit and with estimated threshold values at around 50%.

[Place Table 10 about here]

3.2.2 Growth regression

In growth regression, equation (5), we consider the financial development as the threshold variable and innovation as the regime dependent variable. The endogeneity role of financial development in the finance-growth relationship is undetermined. Evidences from country cross-section, time series and panel data studies provide mixed signals on the causality between financial development and growth. Using cross sectional data, King and Levine (1993a), Levine et al. (2000) and Levine et al. (2003) show evidence of one-way causation, that financial development leads to growth. Subsequent studies cast doubts on the cross-section country evidences. Cross-sectional data may cause

[12] For details see Seo and Shin (2016)

spurious correlation arising from nonstationarity. To overcome this potential issue, Demetriades and Hussein (1996) use time series data for 16 countries and conduct cointegration test, they find evidence of bi-directionality and even evidence of reverse causality. Also, they find that the causal relationship between financial development and growth is country-specific. However, time series evidence may also be unreliable due to the short time span of data. A good option may be the use of panel data. Using panel data for ten developing countries Christopoulos and Tsionas (2004) apply a panel cointegration analysis and find evidence in support of the cross-section country studies. Calderón and Liu (2003) use a panel of 105 countries from 1960 to 1994 and find that, in general, financial development leads to growth. However, the effect is heterogeneous across countries and larger in developing countries. Moreover, they find that Granger causality test shows a bi-directional causality between financial development and growth.

In sum, the above evidence reveal the possibility of reverse causality between financial development and growth. This leads us to consider the threshold variable (the indicator of financial development) as endogenous. Regarding the endogeneity issue of other covariates, innovation may also be endogenously determined by economic development. High income countries typically invest more in R&D activities and hence promote innovation. Government spending, trade, inflation, schooling and investment may also be endogenous due to reverse causality and omitted variable issues. To account for the endogeneity issues, we use the lagged threshold variable, regime dependent variable, dependent variable and other covariates as instruments.

Table 11 summarizes the basic results of the dynamic panel threshold regression for every financial development indicator, estimating equation (5). Column 1 shows the results from the use of private credit as financial development indicator. The coefficient of patent is positive and significant for the lower regime, while it is negative at the upper regime. The estimated threshold value is 58.4% of GDP. The p-value of the linearity test shows a significant non-linearity between the two regimes. Using alternative indicators of financial development, we obtain similar results, except for liquidity. Specifically, banking credit and domestic credit generate a threshold value of 58.5% and 57.7%, respectively. However, for liquidity liability both lower and upper regime show negative effect, while the estimated threshold is 136.7%. One possible reason for the high estimated threshold value for liquidity liability is that the tail of liquidity density is longer than the others. The Kernel density of the four indicators are plotted in Figure A3 in the appendix. Obviously, the density of liquidity liability is significantly right-skewed, which may explain the relatively larger threshold value.

[Place Table 11 about here]

3.2.3 Robustness checks

As a robustness check we re-examine our threshold estimations taking into account the R&D spending as an alternative indicator of innovation. Tables A3 and A4 report the innovation and growth threshold estimations, respectively. The results indicate that the key non-linear relationship and estimated threshold values, reported in the previous subsections, remain consistent.

We also provide an additional robustness check taking into account the utility models, as an additional indicator of innovation. In this case we re-estimate the results for the growth threshold equation (see Table A5) and we find that the estimated threshold remains around the level of 60% as a share of GDP, which is consistent with the results we obtained using patents (see Table 11) and the results we obtained using R&D spending (see Table A4). Therefore, these robustness checks indicate the validity and consistency of our baseline results.

3.2.4 Discussion

Most of the estimated threshold values in finance-growth literature are between 53% and 100%. For example Cecchetti and Kharroubi (2012) and Arcand et al. (2015) estimate a threshold of around 100%, Masten et al. (2008) between 53% and 70%, Law and Singh (2014) at 88%, and Samargandi et al. (2015) at 91%. In our sample, the estimated threshold values are at about 60%. While this value is towards the smaller value of the range reported in the related literature, we argue that this is not due to the sample selection issue, rather the econometric method employed and the potential impact of financial integration across Europe and the world. As a comparision, we apply the quadratic regression by including the square term of financial development indicators and the Kremer et al. (2013)'s panel threshold model to our current sample. To find out the optimal value, the quadratic regression use Lind and Mehlum U-shape test to decide whether the nonlinear effect exists or not and where the threshold value lies. All the quadratic regressions are estimated using system-GMM. Kremer et al. (2013)'s panel threshold model includes lagged dependent variable as the only instrument variable, without taking into account the endogeneity of threshold variable, regime dependent variable, and other covariates. The results in table A6 show that both methods give very large threshold values, which is consistent with the threshold documented in previous studies. In this sense, the large threshold value documented in previous studies may be biased.

In addition, our sample contains 17 European countries from 1990 to 2016. Therefore, our threshold value cannot be completely attributed to the differences in the econometric tools, but it also relates to financial integration across European countries and the rest of the world. Financial integration may enhance the positive effect of financial development on innovation and growth, thus may lead to a smaller threshold value of financial development. One direct evidence is from Masten et al. (2008), where using data from European countries they document a credit-to-GDP threshold between 53-70%, which is similar to our work.

In Table 12 we provide an additional test by re-estimating equation (5) considering the financial development as both the threshold variable and the regime dependent variable. This way we test the threshold effect between finance and growth. Therefore, equation (5) becomes:

$$y_{it} = \rho y_{it-1} + \beta_L FD_{it} * I(FD_{it} \leq \gamma) + \beta_H FD_{it} * I(FD_{it} > \gamma) + \theta \mathbf{Z}_{it} + u_i + \tau_t + e_{it} \tag{9}$$

The results indicate an estimated threshold value of about 60%, which is very close with the results from the previous sub-section presented in Tables 11 and A3. This shows that the results we obtained in the previous sub-section, where we allowed for innovation to switch according to the financial indicator, remain valid even if we do not consider innovation as a regime dependent variable. Therefore, innovation does not affect significantly the estimated threshold of financial development, but it seems to be significantly affected by the level of financial development.

[Place Table 12 about here]

3.2.5 Theoretical explanation

Evidences in Tables 10, 11, and 12 reveal two important economic implications. First, we show that financial development imposes diminishing effect on rate of innovation, such a diminishing effect may slow down economic growth. In this sense, our findings provide a channel through which "too much finance" may harm growth. There may exist three channels through which this diminishing effect works. First, financial development reduces the rate of innovation and thus the productivity growth. In Rajan and Zingales (1998), they show that financial development causes the productivity growth in a unidirectional way. Levine et al. (1998) also shows that productivity growth is the main channel linking financial development to growth. These studies indicate productivity growth as a major channel through which financial development affects growth. Therefore, the negative effect of financial development on growth may be attributed to its potential negative effect on productivity growth. Follow this logic, Aghion et al. (2018) has documented an inverted U-shaped relationship between financial development and productivity growth. We show explicitly that the diminishing effect of financial development on rate of innovation could be the source of inverted U-shape relationship between financial development and productivity growth. In this sense, we close the FD-innovation-productivity-growth chain. Second, FD may reduce both the quantity and quality of innovation. This also causes a decline in productivity growth and aggregate growth. Finally, high level of financial development induces volatility in firm sales growth (Wang and Wen (2009)), signalling a downward expectation on the returns of investment. This may reduce the investment in risky projects such as R&D activities. Lower R&D expenditure may slow down the rate of innovation output, and thus the innovation-led growth.

The second implication is that financial development may make innovations less effective in promoting economic growth. In other words, given a unit increase in innovation, the contribution of innovation is smaller in countries with higher level of financial development. Why? We think that an innovation will not be effective in promoting productivity and aggregate growth until necessary complementary inventions and follow-up investment in productive capital occurs. As credit market develops, bank and firm develop close ties. This close firm-bank ties may facilitate firms to access credit, but it may also prevent firms from involving risky projects such as R&D activities (Weinstein and Yafeh (1998)), causing less productive but more pledgeable projects to be easily financed (Cecchetti et al. (2015)). The results in table A3 also confirm this argument. The relatively less investment of productive capital may prolong the implementation and restructuring lags and reduce the contribution of innovation on productivity and economic growth (Gordon (2018)).

4 Conclusion

This paper has empirically tested the hypothesis that an expansion in financial sector would hurt innovation and innovation-led growth, using a panel of 50 countries over 1990-2016. The results from a linear system-GMM shows that countries with higher level of financial development are associated with a relatively low rate of innovation. Furthermore, this vanishing effect between finance and innovation would finally transmit to innovation-led growth. We find that the positive effect of innovation on growth is smaller or even insignificant for countries with developed financial sector. These conclusions are robust to the banking crisis, the long run effect of 2007-2008 financial crisis, the ongoing European sovereign debt crisis and alternative indicators of financial development and innovation. To precisely estimate the threshold value at which the vanishing effect starts, a dynamic panel threshold model is employed. We find that, for our sample of countries, innovation starts to have an insignificant effect on output growth when private credit reaches the level of around 60% of GDP. Finally, we have shown that our threshold value is not driven by our sample size and selection but the difference in the tools employed in our work, compared to the related literature, as well as the ongoing regional and international financial integration process.

References

Acemoglu, D., Akcigit, U., and Kerr, W. R. (2016). Innovation network. *Proceedings of the National Academy of Sciences*, 113(41):11483–11488.

Aghion, P., Bergeaud, A., Cette, G., Lecat, R., Maghin, H., et al. (2018). The inverted-u relationship between credit access and productivity growth. Technical report, Centre for Economic Performance, LSE.

Akcigit, U. and Kerr, W. R. (2018). Growth through heterogeneous innovations. *Journal of Political Economy*, 126(4):1374–1443.

Amore, M. D., Schneider, C., and Žaldokas, A. (2013). Credit supply and corporate innovation. *Journal of Financial Economics*, 109(3):835–855.

Arcand, J. L., Berkes, E., and Panizza, U. (2015). Too much finance? *Journal of Economic Growth*, 20(2):105–148.

Asimakopoulos, S. and Karavias, Y. (2016). The impact of government size on economic growth: A threshold analysis. *Economics Letters*, 139:65–68.

Axelson, U. and Bond, P. (2015). Wall street occupations. *The Journal of Finance*, 70(5):1949–1996.

Baker, S. R., Bloom, N., and Davis, S. J. (2016). Measuring economic policy uncertainty. *The Quarterly Journal of Economics*, 131(4):1593–1636.

Benfratello, L., Schiantarelli, F., and Sembenelli, A. (2008). Banks and innovation: Microeconometric evidence on italian firms. *Journal of Financial Economics*, 90(2):197–217.

Borio, C., Kharroubi, E., Upper, C., and Zampolli, F. (2016). Labour reallocation and productivity dynamics: financial causes, real consequences. *BIS Working Papers*, 534.

Boustanifar, H., Grant, E., and Reshef, A. (2017). Wages and human capital in finance: International evidence, 1970–2011. *Review of Finance*, 22(2):699–745.

Brown, J. R., Fazzari, S. M., and Petersen, B. C. (2009). Financing innovation and growth: Cash flow, external equity, and the 1990s r&d boom. *The Journal of Finance*, 64(1):151–185.

Cai, J., Chen, Y., and Wang, X. (2018). The impact of corporate taxes on firm innovation: Evidence from the corporate tax collection reform in china. Technical report, National Bureau of Economic Research.

Calderón, C. and Liu, L. (2003). The direction of causality between financial development and economic growth. *Journal of development economics*, 72(1):321–334.

Caner, M. and Hansen, B. E. (2004). Instrumental variable estimation of a threshold model. *Econometric Theory*, 20(5):813–843.

Cecchetti, S. and Kharroubi, E. (2012). Reassessing the impact of finance on growth. Technical report, Bank for International Settlements.

Cecchetti, S. G., Kharroubi, E., et al. (2015). Why does financial sector growth crowd out real economic growth? Technical Report 490, BIS Working Papers.

Célérier, C. and Vallée, B. (2018). Returns to talent and the finance wage premium. *Working Paper*.

Christopoulos, D. K. and Tsionas, E. G. (2004). Financial development and economic growth: evidence from panel unit root and cointegration tests. *Journal of development Economics*, 73(1):55–74.

Comin, D. and Gertler, M. (2006). Medium-term business cycles. *American Economic Review*, 96(3):523–551.

De la Torre, A., Ize, A., and Schmukler, S. L. (2011). *Financial development in Latin America and the Caribbean: the road ahead*. The World Bank.

Demetriades, P. O. and Hussein, K. A. (1996). Does financial development cause economic growth? time-series evidence from 16 countries. *Journal of development Economics*, 51(2):387–411.

Döner, A. S. (2017). Innovation during and beyond the economic crisis. In *Global Financial Crisis and Its Ramifications on Capital Markets*, pages 643–659. Springer.

Frame, W. S., White, L. J., et al. (2014). Technological change, financial innovation, and diffusion in banking. *The oxford handbook of banking*, page 271.

Francois, P. and Lloyd-Ellis, H. (2008). Implementation cycles, investment, and growth. *International Economic Review*, 49(3):901–942.

Freeman, C. et al. (1994). *Innovation and growth*. Edward Elgar Publishing.

Gordon, R. J. (2018). Why has economic growth slowed when innovation appears to be accelerating? Technical report, National Bureau of Economic Research.

Gorodnichenko, Y. and Schnitzer, M. (2013). Financial constraints and innovation: Why poor countries dont catch up. *Journal of the European Economic Association*, 11(5):1115–1152.

Griliches, Z., Pakes, A., Hall, B. H., et al. (1986). The value of patents as indicators of inventive activity. Technical report, National Bureau of Economic Research, Inc.

Hansen, B. E. (1999). Threshold effects in non-dynamic panels: Estimation, testing, and inference. *Journal of econometrics*, 93(2):345–368.

Harris, R. D. and Tzavalis, E. (1999). Inference for unit roots in dynamic panels where the time dimension is fixed. *Journal of econometrics*, 91(2):201–226.

Hsu, P.-H., Tian, X., and Xu, Y. (2014). Financial development and innovation: Cross-country evidence. *Journal of Financial Economics*, 112(1):116–135.

King, R. G. and Levine, R. (1993a). Finance and growth: Schumpeter might be right. *Quarterly Journal of Economics*, 108(3):717–737.

King, R. G. and Levine, R. (1993b). Finance, entrepreneurship and growth: Theory and evidence. *Journal of Monetary Economics*, 32(3):513–542.

Klette, T. J. and Kortum, S. (2004). Innovating firms and aggregate innovation. *Journal of political economy*, 112(5):986–1018.

Kremer, S., Bick, A., and Nautz, D. (2013). Inflation and growth: new evidence from a dynamic panel threshold analysis. *Empirical Economics*, 44(2):861–878.

Laeven, L. and Valencia, F. (2013). Systemic banking crises database. *IMF Economic Review*, 61(2):225–270.

Law, S. H., Lee, W. C., and Singh, N. (2018). Revisiting the finance-innovation nexus: Evidence from a non-linear approach. *Journal of Innovation & Knowledge*, 3(3):143–153.

Law, S. H. and Singh, N. (2014). Does too much finance harm economic growth? *Journal of Banking & Finance*, 41:36–44.

Levine, R. et al. (2003). More on finance and growth: more finance, more growth? *Review-Federal Reserve Bank Of Saint Louis*, 85(4):31–46.

Levine, R., Lin, C., and Wei, L. (2017). Insider trading and innovation. *The Journal of Law and Economics*, 60(4):749–800.

Levine, R., Loayza, N., and Beck, T. (2000). Financial intermediation and growth: Causality and causes. *Journal of monetary Economics*, 46(1):31–77.

Levine, R., Zervos, S., et al. (1998). Stock markets, banks, and economic growth. *American Economic Review*, 88(3):537–558.

Love, J. H. and Roper, S. (1999). The determinants of innovation: R & d, technology transfer and networking effects. *Review of Industrial Organization*, 15(1):43–64.

Masten, A. B., Coricelli, F., and Masten, I. (2008). Non-linear growth effects of financial development: Does financial integration matter? *Journal of international money and finance*, 27(2):295–313.

Morales, M. F. (2003). Financial intermediation in a model of growth through creative destruction. *Macroeconomic Dynamics*, 7(3):363–393.

OECD (2012). *OECD Science, Technology and Industry Outlook 2012*.

Park, W. G. (2008). International patent protection: 1960–2005. *Research policy*, 37(4):761–766.

Philippe, A., Peter, H., and Ross, L. (2018). Financial development and innovation-led growth. *Handbook of Finance and Development*, Handbook chapter:3–30.

Quintyn, M. M., Pansini, M. R. V., and Masciandaro, D. (2011). *The economic crisis: did financial supervision matter?* Number 11-261. International Monetary Fund.

Rajan, R. G. (2006). Has finance made the world riskier? *European Financial Management*, 12(4):499–533.

Rajan, R. G. and Zingales, L. (1998). Financial dependence and growth. *American Economic Review*, pages 559–586.

Samargandi, N., Fidrmuc, J., and Ghosh, S. (2015). Is the relationship between financial development and economic growth monotonic? evidence from a sample of middle-income countries. *World Development*, 68:66–81.

Scherer, F. M. et al. (1986). Innovation and growth: Schumpeterian perspectives. *MIT Press Books*, 1.

Schumpeter, J. A. (1934). *The theory of economic development*. Harvard University Press.

Seo, M. H. and Shin, Y. (2016). Dynamic panels with threshold effect and endogeneity. *Journal of Econometrics*, 195(2):169–186.

Squicciarini, M., Dernis, H., and Criscuolo, C. (2013). Measuring patent quality. *OECD Science, Technology and Industry Working Papers*.

Teorell, J., Dahlberg, S., Holmberg, S., Rothstein, B., Alvarado Pachon, N., and Svensson, R. (2018). *The Quality of Government Standard Dataset, version Jan18*. University of Gothenburg. The Quality of Government Institute.

Tobin, J. (1984). On the efficiency of the financial system. *Lloyds Bank Review*, 153:1–15.

Wang, P. and Wen, Y. (2009). Financial development and economic volatility: A unified explanation, federal reserve bank of st. Technical report, Louis Working Paper.

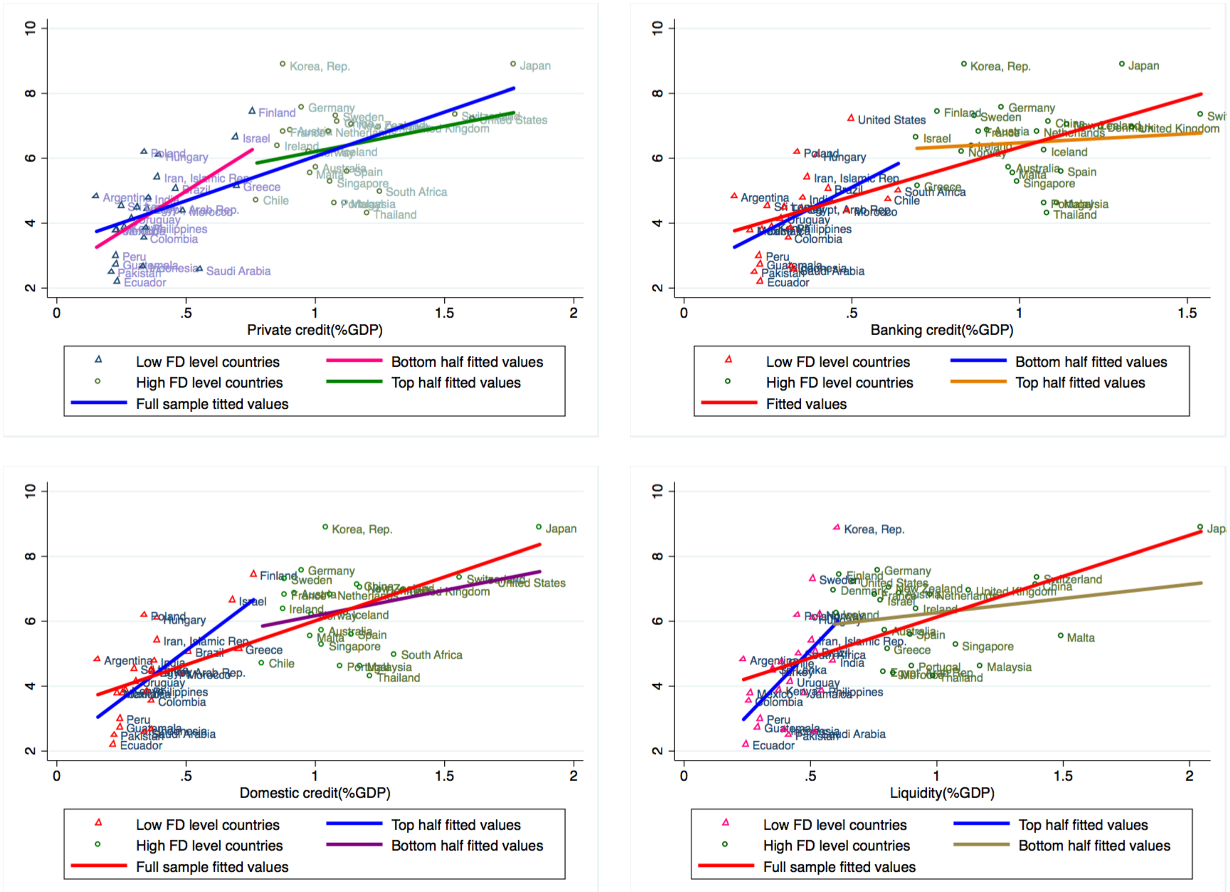
Weinstein, D. E. and Yafeh, Y. (1998). On the costs of a bank-centered financial system: Evidence from the changing main bank relations in japan. *The journal of Finance*, 53(2):635–672.

Xiao, S. and Zhao, S. (2012). Financial development, government ownership of banks and firm innovation. *Journal of International Money and Finance*, 31(4):880–906.

Table 1: Summary statistics

Variable	Mean	Median	Std. Dev.	Min.	Max.	N
	Innovation regression					
Patent	5.351	5.353	1.726	1.075	9.169	300
Utility models	3.808	3.747	2.273	-1.531	7.985	294
R&D	1.266	0.892	1.054	0.05	4.26	276
FDI	0.048	0.021	0.169	-0.04	2.691	300
GDP/capita	9.773	9.946	0.851	7.502	11.311	300
Population	17.003	17.096	1.651	12.471	21.039	300
Schooling	8.906	9.06	2.654	2.42	13.4	300
IP	3.435	3.68	1.051	0.2	4.875	300
	Growth regression					
Growth rate	0.023	0.019	0.025	-0.045	0.244	300
Govt	0.163	0.164	0.05	0.055	0.3	300
Trade	0.754	0.601	0.587	0.156	4.109	300
Investment	0.237	0.228	0.058	0.098	0.474	300
Inflation	0.195	0.032	1.365	-0.017	16.672	300
Initial GDP/capita	9.496	9.509	0.877	7.502	10.755	300
	Indicators of Financial Development					
Private credit	0.742	0.685	0.479	0.079	2.223	300
Banking credit	0.674	0.567	0.439	0.066	2.223	300
Domestic credit	0.756	0.651	0.495	0.115	2.359	300
Liquidity	0.690	0.602	0.392	0.137	2.126	300
Banking crisis	0.23	0	0.422	0	1	300

Figure 1: Financial development and innovation



Note: Countries are sorted according to the level of financial development(FD). This figure splits the countries into two groups: low FD countries and high FD countries. Each group contains 25 countries. This figure uses patent as proxy for innovation.

Table 2: Financial development and Innovation: 1990-2016

	Dependent var: Percentage change in patents				
	Full	**MIC**	**HIC**	**LFD**	**HFD**
L.Patent	0.024	-0.258*	0.006	-0.273***	-0.021
	(0.073)	(0.145)	(0.049)	(0.088)	(0.064)
Private credit	0.353*	0.394**	0.183	0.837**	0.229
	(0.181)	(0.194)	(0.158)	(0.401)	(0.153)
FDI	0.086	9.877	0.139***	-0.975	-0.118
	(0.082)	(10.310)	(0.048)	(1.229)	(0.344)
Population	0.019	0.161***	0.033	0.121**	0.004
	(0.048)	(0.060)	(0.022)	(0.060)	(0.029)
GDP/capita	0.191	-0.275	0.194	0.452	0.109
	(0.336)	(0.553)	(0.251)	(0.347)	(0.249)
Schooling	-0.115**	0.080	-0.089***	0.015	-0.072
	(0.046)	(0.121)	(0.027)	(0.064)	(0.054)
IP	-0.039	-0.064	-0.092	-0.020	0.072
	(0.133)	(0.181)	(0.074)	(0.137)	(0.121)
Obs	250	110	140	125	125
Countries	50	22	28	25	25
AR(2) test	0.130	0.232	0.392	0.250	0.215
Hansen J test	0.240	0.859	0.365	0.505	0.483

Note: Robust standard errors in parentheses. All variables are five years average values; Windmeijer correction method is applied for each regression; MIC: Middle income countries; HIC: High income countries; LFD: Low financial development countries; HFD: High financial development countries. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Financial development, Innovation, and Growth: 1990-2016

	Dependent var: Growth of GDP per capita				
	Full	**MIC**	**HIC**	**LFD**	**HFD**
L.Growth	0.170	-0.119	-0.246**	0.041	0.097
	(0.366)	(0.189)	(0.098)	(0.381)	(0.183)
Patent	0.004*	0.011**	0.002	0.008**	0.001
	(0.002)	(0.005)	(0.005)	(0.004)	(0.003)
Govt	-0.070	-0.262***	0.001	-0.122*	-0.001
	(0.043)	(0.082)	(0.042)	(0.067)	(0.046)
Trade	0.004*	0.004	0.006**	0.006	0.006***
	(0.002)	(0.010)	(0.003)	(0.010)	(0.002)
Investment	-0.029	-0.012	0.309***	0.057	0.153***
	(0.136)	(0.117)	(0.109)	(0.075)	(0.058)
Inflation	-0.012	-0.001	0.005	-0.006	-0.120
	(0.019)	(0.032)	(0.052)	(0.029)	(0.166)
Schooling	0.000	0.001	0.000	0.000	0.001
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Initial	-0.009**	-0.011	-0.023**	-0.009	-0.013***
	(0.004)	(0.009)	(0.009)	(0.007)	(0.004)
Obs	250	110	140	125	125
Countries	50	22	28	25	25
AR(2) test	0.236	0.120	0.145	0.152	0.433
Hansen J test	0.187	0.667	0.148	0.357	0.126

Note: Standard errors in parentheses. All variables are five years average values; Windmeijer correction method applied for each regression; MIC: Middle income countries; HIC: High income countries; LFD: Low financial development countries; HFD: High financial development countries. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: The effect of innovation on growth with level of financial development:1990-2016

	Dependent var: Growth rate of GDP per capita			
	Private credit	**Banking credit**	**Domestic credit**	**Liquidity**
L.Growth	-0.009	0.026	-0.001	-0.011
	(0.113)	(0.287)	(0.104)	(0.153)
Patent	0.012***	0.014**	0.014***	0.010***
	(0.003)	(0.005)	(0.003)	(0.003)
FD*Patent	-0.006**	-0.006*	-0.006**	-0.005*
	(0.003)	(0.004)	(0.003)	(0.003)
Govt	-0.066	-0.028	-0.095*	-0.056
	(0.051)	(0.057)	(0.050)	(0.042)
Trade	0.005	0.009**	0.005*	0.009**
	(0.003)	(0.004)	(0.003)	(0.004)
Investment	0.096	0.078	0.092	0.116
	(0.067)	(0.067)	(0.061)	(0.082)
Inflation	-0.075	-0.056	-0.072	-0.056
	(0.063)	(0.055)	(0.059)	(0.042)
Schooling	0.001	-0.000	0.001	0.000
	(0.002)	(0.001)	(0.002)	(0.002)
Initial	-0.007**	-0.010***	-0.008***	-0.013***
	(0.003)	(0.004)	(0.003)	(0.004)
Obs	250	250	250	250
Countries	50	50	50	50
AR(2) test	0.152	0.173	0.172	0.119
Hansen J test	0.918	0.769	0.956	0.598

Note: Standard errors in parentheses. All variables are five years average values; Windmeijer correction method is applied for each regression; FD is the indicators of financial development, it includes Banking credit, private credit, liquidity liability, and domestic credit. FD*Patent is the interaction between financial development and patent. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Financial development in crisis and tranquil period

Vars	Ave. (BC=1)	Ave. (BC=0)	diff	standard error	t-statistics	p-value
PC1	0.90	0.67	-0.23***	0.056	-4.019	0.000
PC2	0.83	0.61	-0.22***	0.052	-4.217	0.000
LL	0.75	0.64	-0.11**	0.045	-2.204	0.027
DC	0.92	0.71	-0.21***	0.041	-5.037	0.000

Notes: PC1 refers to private credit by banks and other financial institutions(%GDP); PC2 refers to private credit by deposite money banks(%GDP); LL is liquidity liability(%GDP). DC is domestic private credit(%GDP). BC is short for banking crisis, it equals to 1 if there is banking crisis event in that year, and 0 if otherwise. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: Banking crisis, innovation, and growth:1990-2016

	Dependent var: Growth rate		
	(1)	**(2)**	**(3)**
L.Growth	0.520	0.363	0.087
	(0.368)	(0.283)	(0.201)
Patent	0.007***	0.006***	0.007**
	(0.003)	(0.002)	(0.004)
BC	-0.002	-0.010	0.000
	(0.031)	(0.032)	(0.030)
BC*Patent	-0.001	0.000	-0.001
	(0.005)	(0.006)	(0.005)
Initial	-0.012***	-0.009***	-0.012***
	(0.004)	(0.003)	(0.004)
Govt		-0.048	-0.070*
		(0.033)	(0.041)
Trade		0.005*	0.006**
		(0.003)	(0.003)
Schooling		-0.001	-0.001
		(0.001)	(0.001)
Investment			-0.041
			(0.066)
Inflation			0.006
			(0.030)
Obs	250	250	250
Countries	50	50	50
AR(2) test	0.618	0.538	0.115
Hansen J test	0.532	0.603	0.152

Note: Standard errors in parentheses. All variables are five years average values; Windmeijer correction method is applied for each regression; BC is short for banking crisis, it equals to 1 if there is banking crisis event in that year, and 0 if otherwise. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 7: Impact of financial crisis and European debt crisis on innovation recovery:2009-2016

	High income	**Middle income**	**High QOG**	**Low QOG**
	Panel A: Innovation resilience post 2007-2008 financial crisis			
Sinking ratio	39.2%	22.7%	38.4%	25%
Ave. years to recover	0.50	1.43	0.43	1.39
Ave. years of first turning point	0.34	0.33	0.28	0.24
Ratio of negative growth since 2010	67.86%	50%	69.23%	50%
	Panel B: Financial development since 2010(mean values)			
Banking credit	94.31%	39.47%	101.93%	39.23%
Private credit	102%	44.05%	112.91%	43.79%
Liquidity	89.18%	52%	92.26%	51.99%
Domestic credit	99.26%	45.71%	112.39%	44.71%

Note: Financial crisis between 2007 and 2008. Take year 2009 as the initial year post crisis. **Sinking ratio** is defined as the ratio of countries whose innovation level do not recover back to its pre-crisis level through the period examined in our sample; **Average years to recover** refers to the average years needed to return back to pre-crisis level for those recovery countries; **Average years of first turning point** calculates the average years needed for the first positive growth of innovation post crisis. **Ratio of negative growth since 2010** measures the ratio of countries with negative average growth rate of innovation since 2010. Pre-crisis innovation level are calculated as the average innovation level of 2005 and 2006.

Table 8: The impact of post financial crisis and european sovereign debt crisis on innovation

	Dependent var: Growth of patent			
	Private credit	**Banking credit**	**Domestic credit**	**Liquidity**
L.Patent	-0.116	-0.122	-0.122	-0.028
	(0.100)	(0.109)	(0.098)	(0.055)
LC	0.133	0.104	0.093	0.126
	(0.144)	(0.140)	(0.122)	(0.111)
FD	0.472***	0.425***	0.377***	0.187
	(0.129)	(0.114)	(0.143)	(0.186)
LC*FD	-0.266**	-0.271**	-0.200*	-0.254**
	(0.135)	(0.133)	(0.111)	(0.126)
FDI	0.305	0.365	0.309	-0.386
	(0.427)	(0.418)	(0.421)	(0.573)
Population	0.066	0.088	0.066	0.032
	(0.075)	(0.080)	(0.082)	(0.066)
GDP/capita	0.374	0.395	0.412	0.146
	(0.428)	(0.489)	(0.486)	(0.372)
Schooling	-0.079	-0.065	-0.082	-0.046
	(0.062)	(0.066)	(0.065)	(0.062)
IP	-0.049	-0.054	-0.049	0.024
	(0.090)	(0.092)	(0.094)	(0.090)
Obs	250	250	250	250
Countries	50	50	50	50
AR(2) test	0.121	0.105	0.112	0.118
Hansen J test	0.542	0.670	0.566	0.664

Note: Robust standard errors in parentheses. All variables are five years average values; Windmeijer correction method is applied for each regression; FD is the indicators of financial development, it includes Banking credit, private credit, liquidity liability, and domestic credit. LC is a dummy equals to 1 if after 2009, and it is 0 if otherwise. LC*FD is the interaction between financial development and LC. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 9: Ruling out the the impact of post financial crisis and european sovereign debt crisis on innovation: 1990-2009

	Dependent var: Growth of GDP per capita				
	Full	**MIC**	**HIC**	**LFD**	**HFD**
L.Growth	0.188	-0.013	-0.300**	-0.162	-0.081
	(0.354)	(0.239)	(0.146)	(0.141)	(0.345)
Patent	0.003*	0.014***	-0.006	0.005**	-0.000
	(0.002)	(0.005)	(0.004)	(0.002)	(0.003)
Govt	-0.021	-0.173	0.041	-0.040	0.079
	(0.031)	(0.129)	(0.104)	(0.061)	(0.061)
Trade	0.002	0.007	0.000	0.000	0.004
	(0.002)	(0.008)	(0.004)	(0.008)	(0.004)
Investment	0.092	-0.113	0.693*	0.035	0.265**
	(0.131)	(0.086)	(0.401)	(0.103)	(0.111)
Inflation	-0.002	0.029	-0.027	0.003	-0.058
	(0.015)	(0.025)	(0.088)	(0.019)	(0.096)
Schooling	0.000	0.000	0.003	0.001	-0.000
	(0.001)	(0.002)	(0.003)	(0.001)	(0.002)
Initial	-0.009***	-0.019**	-0.021***	-0.010*	-0.013***
	(0.002)	(0.009)	(0.008)	(0.005)	(0.004)
Obs	150	66	84	75	75
Countries	50	22	28	25	25
AR(2) test	0.236	0.089	0.242	0.106	0.221
Hansen J test	0.183	0.518	0.741	0.543	0.127

Note: Robust standard errors in parentheses. All variables are five years average values; Windmeijer correction method is applied for each regression. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 10: Dynamic Panel Threshold Analysis: Innovation regression

	Private credit	**Banking credit**	**Domestic credit**	**Liquidity**
Threshold($\hat{\gamma}$)	0.480***	0.479***	0.527***	0.496***
	(0.043)	(0.044)	(0.033)	(0.130)
Financial development				
$\hat{\beta}_L(FD \leq \gamma)$	1.339***	1.246***	1.184***	0.329**
	(0.237)	(0.219)	(0.215)	(0.176)
$\hat{\beta}_H(FD > \gamma)$	0.030	0.096	-0.060	-0.345***
	(0.234)	(0.218)	(0.204)	(0.109)
L.Patent	0.632***	0.596***	0.603***	0.570***
	(0.028)	(0.039)	(0.029)	(0.038)
FDI	-0.048*	-0.025***	-0.024*	-0.034
	(0.026)	(0.033)	(0.010)	(0.022)
Population	0.048	0.095	0.230	-0.109
	(0.444)	(0.327)	(0.169)	(0.319)
GDP/capita	0.302***	0.359*	0.069	0.486***
	(0.068)	(0.097)	(0.106)	(0.094)
IP	0.259***	0.237***	0.243***	0.202***
	(0.042)	(0.044)	(0.032)	(0.038)
Schooling	-0.037	-0.031	0.023***	0.032
	(0.025)	(0.025)	(0.007)	(0.028)
Obs	250	250	250	250
Countries	50	50	50	50
Linearity test(p-value)	0.000	0.000	0.000	0.000
m_2	0.497	0.310	0.234	0.14
J(p-value)	0.94	0.94	0.36	0.94

Note: The null of linearity test is H_0: $\hat{\beta}_L = \hat{\beta}_H$. m_2 tests for lack of second order serial correlation in the residuals. If this test rejects the null hypothesis, then the moment restrictions are not valid and the GMM estimator will be inconsistent. The J test is a specification test which means that if it rejects, either the orthogonality conditions, or other assumptions, or both are false. Robust standard errors in the parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 11: Dynamic Panel Threshold Analysis: Growth regression

	Private credit	**Banking credit**	**Domestic credit**	**Liquidity**
Threshold($\hat{\gamma}$)	0.584***	0.585***	0.577***	1.367***
	(0.017)	(0.023)	(0.032)	(0.067)
Innovation				
$\hat{\beta}_L$(FD$\leq\gamma$)	0.010***	0.009***	0.006*	-0.009***
	(0.002)	(0.001)	(0.003)	(0.001)
$\hat{\beta}_H$(FD$>\gamma$)	-0.008***	-0.007***	-0.008***	-0.005***
	(0.002)	(0.001)	(0.002)	(0.001)
L.Growth	-0.440***	-0.479***	-0.380***	-0.392***
	(0.016)	(0.037)	(0.018)	(0.031)
Schooling	0.008***	0.008***	0.009***	0.009***
	(0.000)	(0.001)	(0.001)	(0.001)
Govt	-0.514***	-0.733***	-0.572***	-0.936***
	(0.045)	(0.072)	(0.074)	(0.082)
Investment	0.221***	0.248***	0.256***	0.241***
	(0.019)	(0.018)	(0.013)	(0.017)
Trade	0.013***	0.017***	0.016***	0.015***
	(0.003)	(0.004)	(0.002)	(0.004)
Inflation	0.004	0.005	-0.011	-0.033***
	(0.003)	(0.005)	(0.006)	(0.011)
Obs	250	250	250	250
Countries	50	50	50	50
Linearity test(p-value)	0.000	0.000	0.000	0.000
m_2	0.03	0.05	0.15	0.04
J(p-value)	0.36	0.94	0.36	0.99

Note: The null of linearity test is H_0: $\hat{\beta}_L = \hat{\beta}_H$. m_2 tests for lack of second order serial correlation in the residuals. If this test rejects the null hypothesis, then the moment restrictions are not valid and the GMM estimator will be inconsistent. The J test is a specification test which means that if it rejects, either the orthogonality conditions, or other assumptions, or both are false. Robust standard errors in the parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

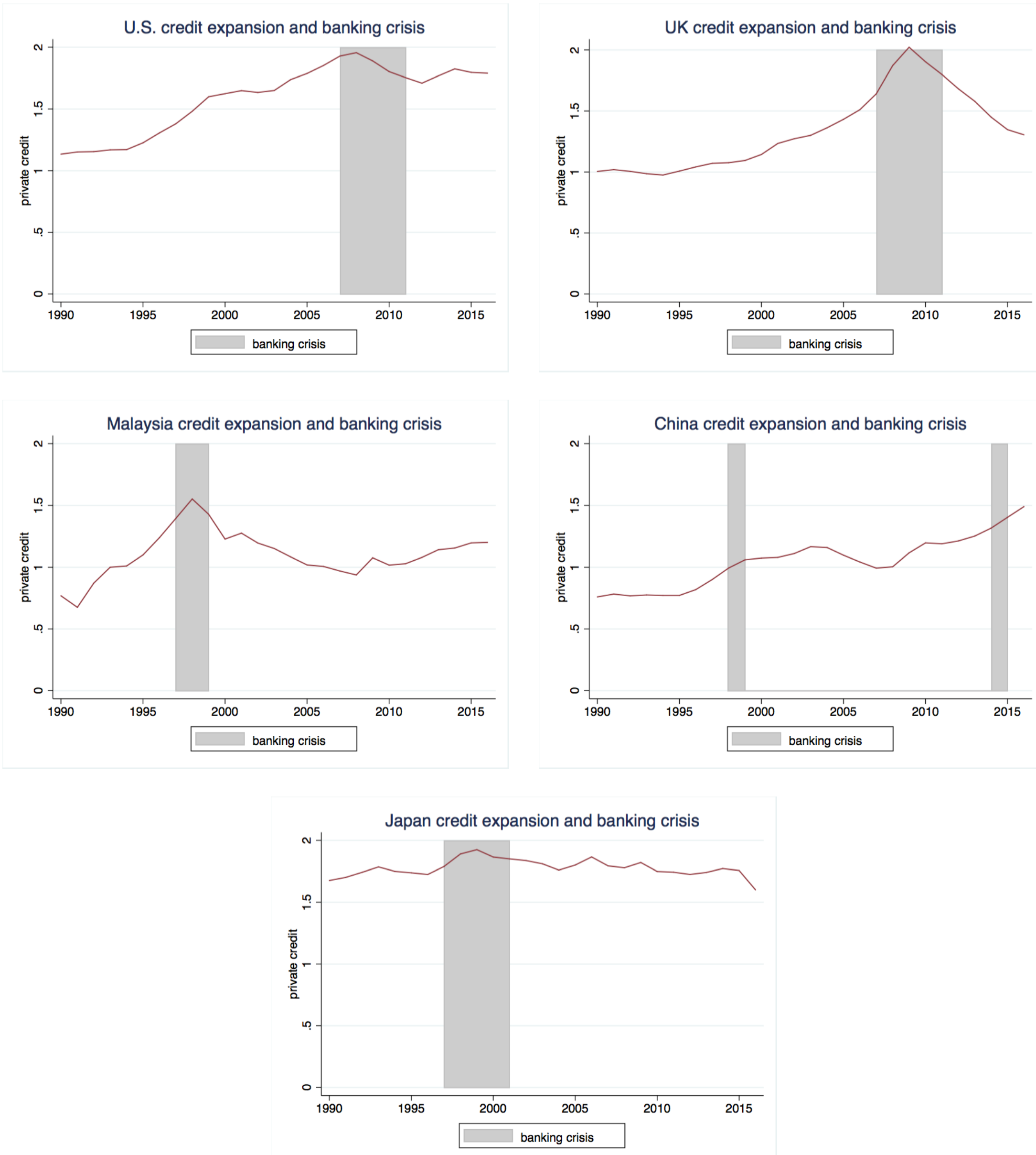
Table 12: Dynamic Panel Threshold Analysis: Growth regression without interaction between finance and patent

	Private credit	**Banking credit**	**Domestic credit**	**Liquidity**
Threshold($\hat{\gamma}$)	0.591***	0.598***	0.611***	0.730***
	(0.034)	(0.033)	(0.025)	(0.252)
Financial development				
$\hat{\beta}_L$(FD$\leq\gamma$)	0.034**	0.052***	0.022*	0.086*
	(0.015)	(0.008)	(0.010)	(0.047)
$\hat{\beta}_H$(FD$>\gamma$)	-0.056***	-0.039***	-0.048***	0.012
	(0.015)	(0.006)	(0.008)	(0.027)
L.Growth	-0.271***	-0.381***	-0.312***	-0.034
	(0.027)	(0.055)	(0.043)	(0.103)
Schooling	0.005***	-0.002	-0.002	-0.009*
	(0.001)	(0.005)	(0.002)	(0.005)
Govt	-0.004***	0.001	-0.001	-0.005
	(0.000)	(0.004)	(0.026)	(0.006)
Investment	0.069***	0.061***	0.072***	0.109
	(0.012)	(0.014)	(0.019)	(0.075)
Trade	-0.006	0.025***	0.027	0.004
	(0.005)	(0.005)	(0.004)	(0.023)
Inflation	-0.008***	-0.008***	-0.009***	-0.001
	(0.001)	(0.002)	(0.002)	(0.009)
Obs	250	250	250	250
Countries	50	50	50	50
Linearity test(p-value)	0.000	0.000	0.000	0.000
m_2	0.07	0.05	0.08	0.029
J(p-value)	0.36	0.94	0.94	0.03

Note: The null of linearity test is H_0: $\hat{\beta}_L = \hat{\beta}_H$. m_2 tests for lack of second order serial correlation in the residuals. If this test rejects the null hypothesis, then the moment restrictions are not valid and the GMM estimator will be inconsistent. The J test is a specification test which means that if it rejects, either the orthogonality conditions, or other assumptions, or both are false. Robust standard errors in the parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

A Appendix

Figure A1: Credit Expansion and Banking Crisis



Note: Shaded area indicates a banking crisis in that year. Original database on Banking Crisis is obtained from Laeven and Valencia (2013), Systemic Banking Crises Database(1970-2011). The data from 2012 to 2016 are extended by the author by searching key words that indicates a banking crisis for each country between 2012 and 2016. Key words includes bank run, bank crisis and illiquidity.

Table A1: Robustness check for innovation regression 1: 1990-2016

	Dependent var: Percentage change in patents														
	Banking credit					**Domestic credit**					**Liquidity**				
	Full	**MIC**	**HIC**	**LFD**	**HFD**	**Full**	**MIC**	**HIC**	**LFD**	**HFD**	**Full**	**MIC**	**HIC**	**LFD**	**HFD**
L.Patent	0.007	-0.327**	0.007	-0.160**	0.051	0.020	-0.274*	0.006	-0.316***	0.090	-0.044	-0.361**	-0.013	-0.610*	-0.120
	(0.062)	(0.165)	(0.035)	(0.065)	(0.084)	(0.072)	(0.153)	(0.050)	(0.073)	(0.068)	(0.066)	(0.150)	(0.044)	(0.371)	(0.181)
FD	0.260*	0.621**	0.152	0.626*	0.176*	0.247**	0.414**	0.133	0.840**	0.123	0.302*	0.536***	0.029	0.545**	0.105
	(0.147)	(0.242)	(0.116)	(0.378)	(0.093)	(0.124)	(0.204)	(0.123)	(0.367)	(0.312)	(0.160)	(0.205)	(0.095)	(0.239)	(0.116)
FDI	0.114	12.374	0.151***	-1.398	0.069	0.097	9.934	0.144***	-0.098	0.048	0.109	16.523	-0.205	-0.488*	-0.123
	(0.077)	(13.534)	(0.043)	(1.846)	(0.058)	(0.077)	(10.829)	(0.047)	(0.678)	(0.116)	(0.381)	(12.646)	(0.194)	(0.266)	(0.157)
Population	0.037	0.174**	0.044*	0.087**	-0.026	0.017	0.163**	0.032	0.108**	-0.084	0.017	0.192**	0.014	0.100	0.068
	(0.043)	(0.079)	(0.024)	(0.034)	(0.045)	(0.047)	(0.064)	(0.021)	(0.054)	(0.089)	(0.064)	(0.084)	(0.027)	(0.095)	(0.077)
GDP/capita	0.197	-0.338	0.184	0.195	-0.010	0.174	-0.279	0.252	0.190	-0.477	0.166	-0.353	0.299*	0.856	0.694
	(0.324)	(0.638)	(0.209)	(0.188)	(0.330)	(0.337)	(0.577)	(0.206)	(0.341)	(0.511)	(0.445)	(0.553)	(0.155)	(0.816)	(0.549)
Schooling	-0.095**	0.095	-0.085***	0.025	-0.121***	-0.108**	0.079	-0.091***	0.061	-0.052	-0.092	0.113	-0.091***	0.004	-0.123***
	(0.046)	(0.139)	(0.022)	(0.060)	(0.044)	(0.045)	(0.125)	(0.026)	(0.067)	(0.066)	(0.057)	(0.135)	(0.020)	(0.196)	(0.037)
IP	-0.029	-0.058	-0.084	-0.073	0.067	-0.010	-0.065	-0.091	0.048	0.245*	0.015	-0.080	-0.024	0.145	-0.070
	(0.130)	(0.191)	(0.064)	(0.108)	(0.181)	(0.126)	(0.185)	(0.074)	(0.160)	(0.135)	(0.134)	(0.197)	(0.074)	(0.499)	(0.191)
Obs	250	110	140	125	125	250	110	140	125	125	250	110	140	125	125
Countries	50	22	28	25	25	50	22	28	25	25	50	22	28	25	25
AR(2) test	0.113	0.270	0.360	0.095	0.339	0.116	0.236	0.348	0.365	0.105	0.119	0.295	0.302	0.690	0.130
Hansen J test	0.190	0.818	0.464	0.868	0.362	0.293	0.846	0.365	0.632	0.556	0.143	0.800	0.564	0.814	0.382

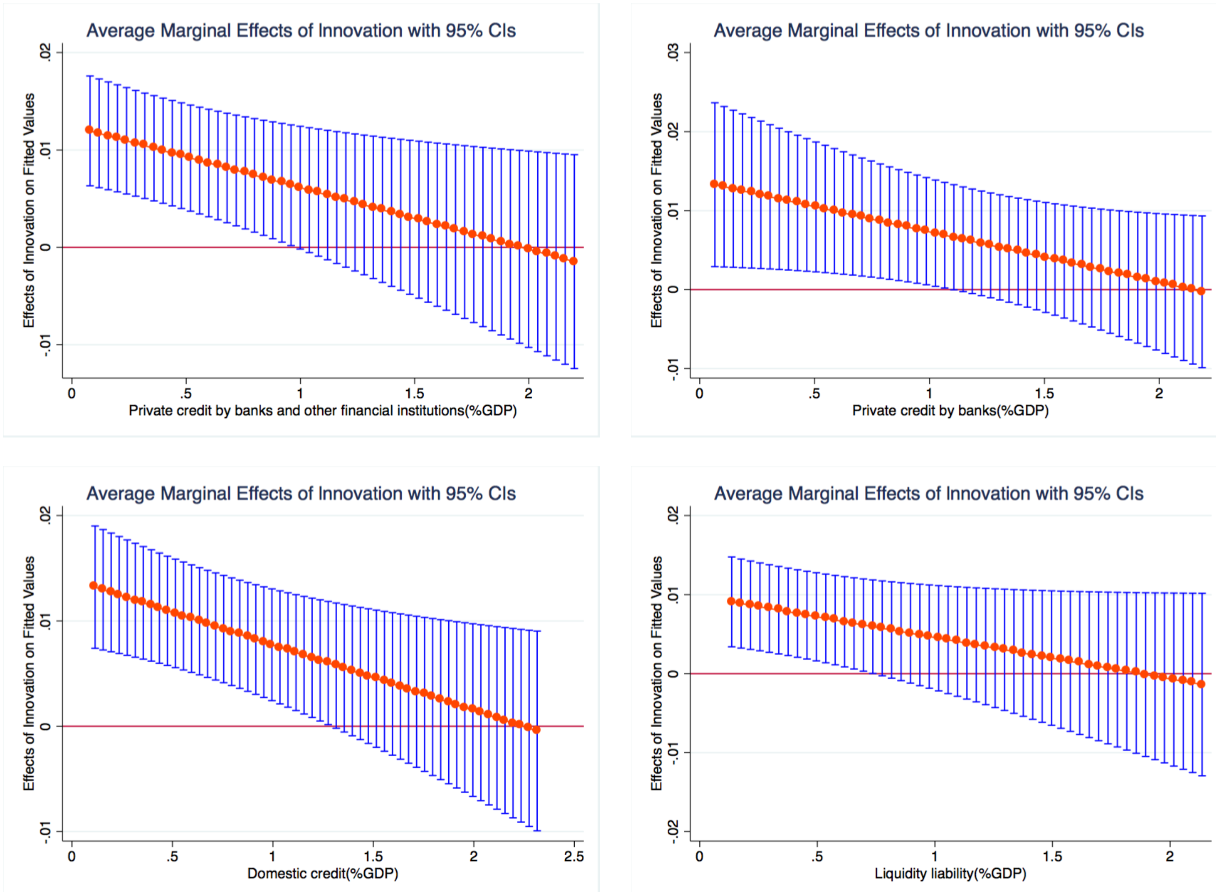
Note: Robust standard errors in parentheses. All variables are five year average values; Windmeijer correction method applied for each regression; For each indicator the high and low financial development group are classified using 50 percentile as cutoff. MIC: middle income countries; HIC: high income countries; LFD: low level of financial development countries; HFD: high level of financial development countries. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A2: Robustness checks for growth regression (2): 1990-2016

	Dependent var: Growth rate of GDP per capita					
	Banking credit		**Domestic credit**		**Liquidity**	
	LFD	**HFD**	**LFD**	**HFD**	**LFD**	**HFD**
L.Growth	-0.097	0.218	0.041	0.097	-0.135	0.080
	(0.252)	(0.194)	(0.381)	(0.183)	(0.276)	(0.252)
Patent	0.010***	-0.006	0.008**	0.001	0.008**	0.003
	(0.003)	(0.008)	(0.004)	(0.003)	(0.003)	(0.004)
Govt	-0.078	-0.010	-0.122*	-0.001	-0.091*	-0.037
	(0.066)	(0.085)	(0.067)	(0.046)	(0.052)	(0.067)
Trade	0.008	0.002	0.006	0.006***	0.001	0.006
	(0.007)	(0.003)	(0.010)	(0.002)	(0.011)	(0.004)
Investment	0.072	0.075	0.057	0.153***	0.089	0.156
	(0.054)	(0.112)	(0.075)	(0.058)	(0.067)	(0.114)
Inflation	-0.019	-0.222	-0.006	-0.120	-0.026	0.113
	(0.040)	(0.262)	(0.029)	(0.166)	(0.038)	(0.095)
Schooling	-0.001	0.002	0.000	0.001	-0.000	0.001
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Initial	-0.011*	-0.014***	-0.009	-0.013***	-0.010**	-0.011*
	(0.006)	(0.004)	(0.007)	(0.004)	(0.005)	(0.006)
Obs	125	125	125	125	125	125
Countries	25	25	25	25	25	25
AR(2) test	0.154	0.413	0.152	0.433	0.127	0.239
Hansen J test	0.512	0.151	0.357	0.126	0.268	0.102

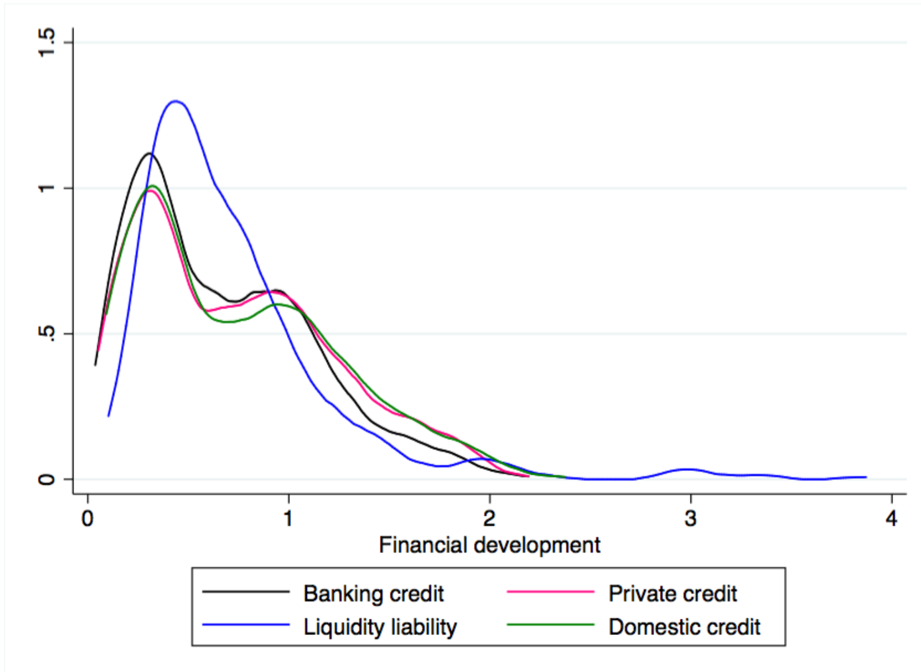
Note: Standard errors in parentheses. All variables are five years average values; Windmeijer correction method applied for each regression; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Figure A2: Average marginal effect of patent on growth



Note: This figure simulates the marginal effect of innovation with changes in the level of financial development. The effect of innovation is assumed to be heterogeneous across countries. The lower and upper limit of interval for each variable is assigned to its min and max value, the step width is set as 0.02. 95% of confidence interval reported

Figure A3: Kernel density of four indicators of financial development



Note: Estimated density of indicators of financial development using Epanechnikov kernal density

Table A3: Dynamic Panel Threshold Analysis: Innovation regression (R&D)

	Dependent var: R&D (% of GDP)			
	Private credit	**Banking credit**	**Domestic credit**	**Liquidity**
Threshold($\hat{\gamma}$)	0.443***	0.441***	0.389***	0.610***
	(0.113)	(0.095)	(0.085)	(0.156)
Financial development				
$\hat{\beta}_L(FD \leq \gamma)$	1.157***	0.879***	1.319***	0.837***
	(0.210)	(0.159)	(0.367)	(0.092)
$\hat{\beta}_H(FD > \gamma)$	-0.054	0.145	0.196	0.016
	(0.039)	(0.149)	(0.352)	(0.160)
L.R&D	0.398***	0.435***	0.294***	0.415***
	(0.057)	(0.055)	(0.066)	(0.033)
FDI	-0.016	-0.274	-0.034*	-0.001
	(0.282)	(0.265)	(0.018)	(0.026)
Population	0.171	-0.140	0.569*	-0.254
	(0.126)	(0.263)	(0.322)	(0.226)
GDP/capita	-0.012	0.164	0.029	0.127**
	(0.026)	(0.109)	(0.106)	(0.065)
IP	0.036	-0.214	0.015	0.072***
	(0.024)	(0.260)	(0.019)	(0.024)
Schooling	0.119**	0.026	0.061***	0.019
	(0.054)	(0.027)	(0.017)	(0.019)
Obs	230	230	230	230
Countries	46	46	46	46
Linearity test(p-value)	0.000	0.000	0.000	0.000
m_2	0.13	0.12	0.1	0.16
J(p-value)	1	1	0.99	0.99

Note: The null of linearity test is H_0: $\hat{\beta}_L = \hat{\beta}_H$. m_2 tests for lack of second order serial correlation in the residuals. If this test rejects the null hypothesis, then the moment restrictions are not valid and the GMM estimator will be inconsistent. The J test is a specification test which means that if it rejects, either the orthogonality conditions, or other assumptions, or both are false. Robust standard errors in the parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A4: Dynamic Panel Threshold Analysis: Growth regression (R&D)

	Private credit	**Banking credit**	**Domestic credit**	**Liquidity**
Threshold($\hat{\gamma}$)	0.531***	0.600***	0.511***	0.316***
	(0.026)	(0.047)	(0.029)	(0.010)
R&D				
$\hat{\beta}_L$(FD$\leq\gamma$)	0.058***	0.023***	0.030***	0.413***
	(0.007)	(0.005)	(0.007)	(0.076)
$\hat{\beta}_H$(FD$>\gamma$)	-0.014**	-0.011***	-0.012**	-0.007
	(0.006)	(0.005)	(0.005)	(0.076)
L.Growth	-0.365***	-0.468***	-0.313***	-0.375***
	(0.031)	(0.041)	(0.041)	(0.037)
Schooling	0.0027***	0.0037***	0.0034***	0.0012
	(0.001)	(0.001)	(0.001)	(0.001)
Govt	-0.193***	-0.4471***	-0.411***	-0.494***
	(0.086)	(0.092)	(0.116)	(0.087)
Investment	0.193***	0.248***	0.213***	0.231***
	(0.021)	(0.013)	(0.022)	(0.023)
Trade	0.0066	0.013***	0.015***	0.013***
	(0.005)	(0.003)	(0.004)	(0.004)
Inflation	-0.026***	-0.015***	-0.0058	-0.077***
	(0.005)	(0.005)	(0.009)	(0.008)
Obs	230	230	230	230
Countries	46	46	46	46
Linearity test(p-value)	0.000	0.000	0.000	0.000
m_2	0.06	0.03	0.12	0.17
J(p-value)	0.98	0.98	0.99	0.99

Note: The null of linearity test is H_0: $\hat{\beta}_L = \hat{\beta}_H$. m_2 tests for lack of second order serial correlation in the residuals. If this test rejects the null hypothesis, then the moment restrictions are not valid and the GMM estimator will be inconsistent. The J test is a specification test which means that if it rejects, either the orthogonality conditions, or other assumptions, or both are false. Robust standard errors in the parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A5: Dynamic Panel Threshold Analysis: Growth regression (Utility models)

	Private credit	**Banking credit**	**Domestic credit**	**Liquidity**
Threshold($\hat{\gamma}$)	0.592***	0.601***	0.572***	0.986***
	(0.032)	(0.027)	(0.268)	(0.067)
Innovation				
$\hat{\beta}_L$(FD$\leq\gamma$)	0.019***	0.017***	0.006*	-0.023***
	(0.001)	(0.002)	(0.002)	(0.005)
$\hat{\beta}_H$(FD$>\gamma$)	-0.007***	-0.011***	-0.007***	-0.005***
	(0.003)	(0.002)	(0.002)	(0.003)
L.Growth	-0.502***	-0.511***	-0.418***	-0.301***
	(0.032)	(0.037)	(0.029)	(0.075)
Schooling	0.005***	0.006***	0.007***	0.015***
	(0.000)	(0.001)	(0.001)	(0.002)
Govt	-0.532***	-0.710***	-0.515***	-0.236
	(0.087)	(0.079)	(0.071)	(0.195)
Investment	0.202***	0.197***	0.171***	0.289***
	(0.021)	(0.018)	(0.022)	(0.092)
Trade	0.013***	0.010***	0.016***	-0.021
	(0.004)	(0.005)	(0.005)	(0.017)
Inflation	0.012**	0.011	-0.007	-0.013
	(0.006)	(0.007)	(0.012)	(0.010)
Obs	245	245	245	245
Countries	49	49	49	49
Linearity test(p-value)	0.000	0.000	0.000	0.000
m_2	0.02	0.04	0.12	0.11
J(p-value)	0.95	0.95	0.99	0.14

Note: The null of linearity test is H_0: $\hat{\beta}_L = \hat{\beta}_H$. m_2 tests for lack of second order serial correlation in the residuals. If this test rejects the null hypothesis, then the moment restrictions are not valid and the GMM estimator will be inconsistent. The J test is a specification test which means that if it rejects, either the orthogonality conditions, or other assumptions, or both are false. Robust standard errors in the parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A6: Threshold estimation using quadratic and Kremer et al. (2013) method: Innovation regression

	Private credit	**Banking credit**	**Liquidity**	**Domestic credit**
	Nonlinear test using quadratic regression			
L.Patent	-0.092	-0.084	0.020	-0.118
	(0.070)	(0.074)	(0.099)	(0.080)
FD	1.906**	1.303**	1.407**	2.137***
	(0.855)	(0.506)	(0.694)	(0.822)
FD^2	-0.774*	-0.513**	-0.810*	-0.939**
	(0.416)	(0.214)	(0.463)	(0.418)
FDI	-0.035	-0.010	0.089	-0.102
	(0.084)	(0.079)	(0.291)	(0.159)
Population	0.004	0.005	0.038	0.006
	(0.054)	(0.044)	(0.084)	(0.056)
GDP/capita	0.119	0.191	0.231	0.308
	(0.220)	(0.218)	(0.343)	(0.315)
Schooling	-0.147***	-0.178***	-0.152*	-0.210***
	(0.044)	(0.039)	(0.086)	(0.063)
IP	0.123	0.157	0.125	0.232*
	(0.151)	(0.163)	(0.187)	(0.133)
_cons	-0.576	-0.915	-2.502	-2.201
	(2.378)	(2.327)	(4.007)	(3.179)
Obs	250	250	250	250
Country	50	50	50	50
AR(2) test	0.140	0.137	0.116	0.132
Hansen J test	0.411	0.409	0.435	0.930
	Lind and Mehlum U-shape test			
$dY/dFD = 0$	1.231	1.268	0.868	1.137
P-value	0.065	0.022	0.062	0.028
	Threshold test using Kremer et al(2013) method			
Threshold estimates				
$\hat{\gamma}$	1.378	1.333	1.649	1.660
95% CI	[1.207 3.057]	[1.207 1.646]	[1.289 1.782]	[1.219 1.717]
Impact of FD				
$\hat{\beta}_L$	0.664**	0.854**	0.326	0.341**
	(0.334)	(0.359)	(0.24)	(0.147)
$\hat{\beta}_H$	0.038	0.019	-0.008	0.044*
	(0.027)	(0.026)	(0.049)	(0.025)
Impact of covariates				
L.Patent	0.065**	0.041	0.028	0.04
	(0.032)	(0.031)	(0.031)	(0.03)
FDI	0.031	0.037	0.042	0.035
	(0.067)	(0.063)	(0.063)	(0.064)
GDP/capita	-0.105*	-0.073	-0.061	-0.085*
	(0.055)	(0.053)	(0.054)	(0.051)
Population	0.064	0.113	0.092	0.052
	(0.147)	(0.152)	(0.158)	(0.156)
Schooling	-0.045***	-0.042***	-0.032***	-0.039***
	(0.011)	(0.009)	(0.011)	(0.009)
IP	0.067***	0.059***	0.056***	0.066***
	(0.016)	(0.014)	(0.017)	(0.015)
$\hat{\delta}$	-0.116	-0.151	-0.074	-0.035
	(0.093)	(0.088)	(0.106)	(0.064)
Obs	300	300	300	300
Country	50	50	50	50

Note: Robust standard errors in parentheses. All variables are five years average values; Windmeijer correction method is applied for each regression; FD is the indicators of financial development, it includes Banking credit, private credit, liquidity liability, and domestic credit. * (p<0.1), ** (p<0.05), *** (p<0.01).

Table A7: Variable Definitions and Sources

Variables	Definition	Source
Patent	Resident applications per 100 billion USD GDP(2011 PPP)(by applicant's origin), natural log of patent	WIPO
Utility models	Resident applications per 100 billion USD GDP(by applicant's origin), natural log of utility models	Authors' construction from WIPO
R&D	Gross domestic spending on R&D as percentage of GDP	OECD&UNESCO
FDI	Foreign direct investment, net inflows (% of GDP)	WDI, World Bank
GDP/capita	GDP per capita(2011 PPP), natural log of GDP per capita	WDI, World Bank
Population	Total population ages 15-64, natural log of total population	WDI, World Bank
Schooling	Average number of years of education received by people ages 25 and older	UN-HDI
IP	Intelectual property right protection index (five years average)	Park's IP database
Growth rate	GDP per capita growth (annual %)	WDI, World Bank
Govt	General government final consumption expenditure (% of GDP)	WDI, World Bank
Trade	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product(% of GDP).	WDI, World Bank
Investment	Gross capital formation (% of GDP)	WDI, World Bank
Inflation	Inflation as measured by the annual percentage change in consumer price index reflects(%)	WDI, World Bank
Initial GDP/capita	Initial GDP per capita, natural log of GDP per capita	WDI, World Bank
Private credit	Private credit by deposit money banks and other financial institutions to GDP.	WBFSD, World Bank
Banking credit	The financial resources provided to the private sector by domestic money banks as a share of GDP.	WBFSD, World Bank
Domestic credit	Domestic credit to private sector refers to financial resources provided to the private sector((% of GDP)).	WBFSD, World Bank
Liquidity	Ratio of liquid liabilities to GDP. Liquid liabilities are also known as broad money, or M3.	WBFSD, World Bank
Banking crisis	A dummy variable is defined as 1 if there is banking crisis in the year, and 0 otherwise	Laeven et al.(2013) and authors' construction

Note: Index of protection for intellectual property right is obatained from Park (2008), the author updates the data to 2015. WIPO: World Intellectual Property Organization; UNESCO: United Nations Educational, Scientific and Cultural Organization; WDI: World Development Indicators; UN-HDI: United Nations Human Development Index; WBFSD: World Bank Financial Structure Database. The financial development missing data for New Zealand is filled using data from Reserve Bank of New Zealand(https://www.rbnz.govt.nz/statistics). Banking Crisis is obtained from Laeven and Valencia (2013), Systemic Banking Crises Database(1970-2011). The data from 2012 to 2016 are extended by the author by searching key words that indicates a banking crisis for each country between 2012 and 2016. Key words includes bank run, bank crisis and illiquidity.